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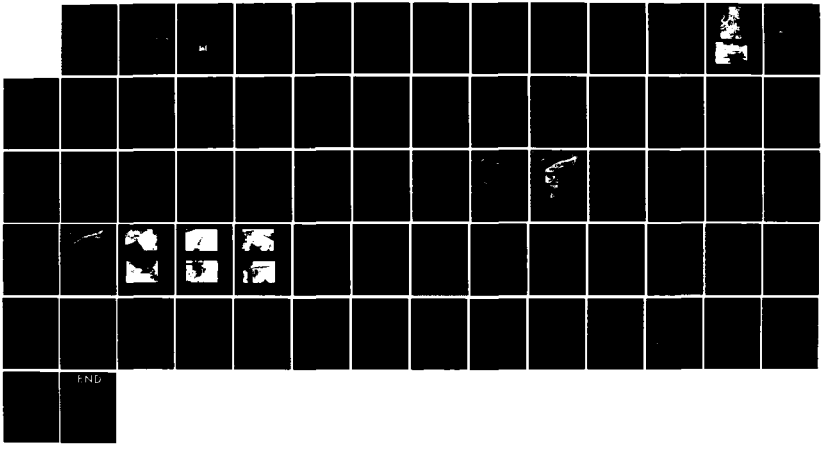

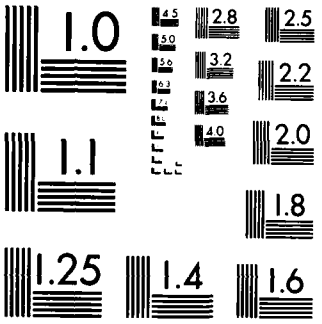

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MERRIMACK RIVER BASIN

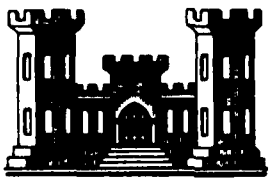
ALLENSTOWN – PEMBROKE, NEW HAMPSHIRE

PEMBROKE DAM

NH 00377

NHWRB 190.02

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
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MARCH 1979

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS, INSPECTION, DAM SAFETY,

Merrimack RIver Basin
Allenstown-Pembroke, New Hampshire
Suncook River

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The dam is a stone masonry gravity dam constructed on bedrock. The dam is about 108 ft. long and 25.6 ft. high. It is small in size with a low hazard potential. It is unlikely that the downstream flows caused by failure of the dam would result in loss of life or serious economic damage. The dam is in poor condition at the present time and requires extensive maintenance.

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PEMBROKE DAM
NH 00377

MERRIMACK RIVER BASIN
PEMBROKE, NEW HAMPSHIRE

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

NATIONAL DAM INSPECTION PROGRAM

PHASE I REPORT

Identification No.:	NH 00377
NHWRB No.:	190.02
Name of Dam:	PEMBROKE DAM
Town:	Pembroke-Allenstown
County and State:	Merrimack County, NH
Stream:	Suncook River
Date of Inspection:	November 7, 1978

BRIEF ASSESSMENT

Pembroke Dam is a stone masonry gravity dam constructed on bedrock. The dam is 108 feet long and approximately 25.6 feet high. The total spillway length is 77 feet and consists of 2 sections at approximately 90° to each other. One leg is 57 feet long and the second leg is 20 feet long. The right end of the dam has an old mill building with abandoned power generating facilities and two sluice gate openings. The two sluice gates, which are no longer operable, are the only outlet works at the dam.

Available records indicate that the dam was originally constructed in 1891 and was altered in 1893. The dam was built to provide power for the mill building located at the right end of the dam. The dam is no longer used to provide power for the mill. Suncook Mills was the owner from 1918 to at least 1948 and probably owned the dam from the time of its construction. According to records obtained by the New Hampshire Water Resources Board (NHWRB), the dam is owned by Thomas Hodgson and Sons, Inc., of Suncook, N.H.

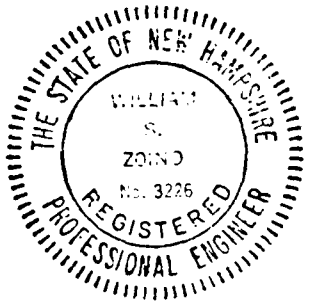
The dam lies on the Suncook River. The drainage area for the structure is 259 square miles. The dam's maximum impoundment of 34 acre-feet and height of 25.6 feet place the dam in the SMALL size category. In the event of a failure of Pembroke Dam, it is unlikely that the downstream flows caused by the failure would result in loss of life or serious economic damage. For this reason, the dam is assigned a LOW hazard potential classification.

Based on the size and hazard classification, and in accordance with the Corps of Engineers' guidelines, the Test Flood (TF) would be between the 50 and 100-year floods.

Since the hazard potential is on the low side of the LOW category, the test flow was taken as the 50-year flood. The test flow for the 50-year flood is 12,190 cfs and would result in an overtopping of the dam of 8.4 feet. Analyses revealed that high flows cause the dam to be submerged by the tailwater. Therefore, the downstream flows would not be greatly affected by a failure of the dam.

Pembroke Dam is in POOR condition at the present time and requires extensive maintenance. It is recommended that further investigations be made into the source of seepage at the mill foundation and that this seepage and the seepage through the spillway be brought under control. It is recommended that the sluice gates be rehabilitated or structurally sealed. A recommended remedial measure is to concrete face all stone masonry. In light of the dam's POOR condition, technical inspections should be made every year.

The recommendations and improvements outlined above should be implemented within one year of receipt of this report by the owner.



William S. Zoino
New Hampshire Registration 3226

Nicholas A. Campagna, Jr.
California Registration 21006

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Test Flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the Test Flood should not be interpreted as necessarily posing a highly inadequate condition. The Test Flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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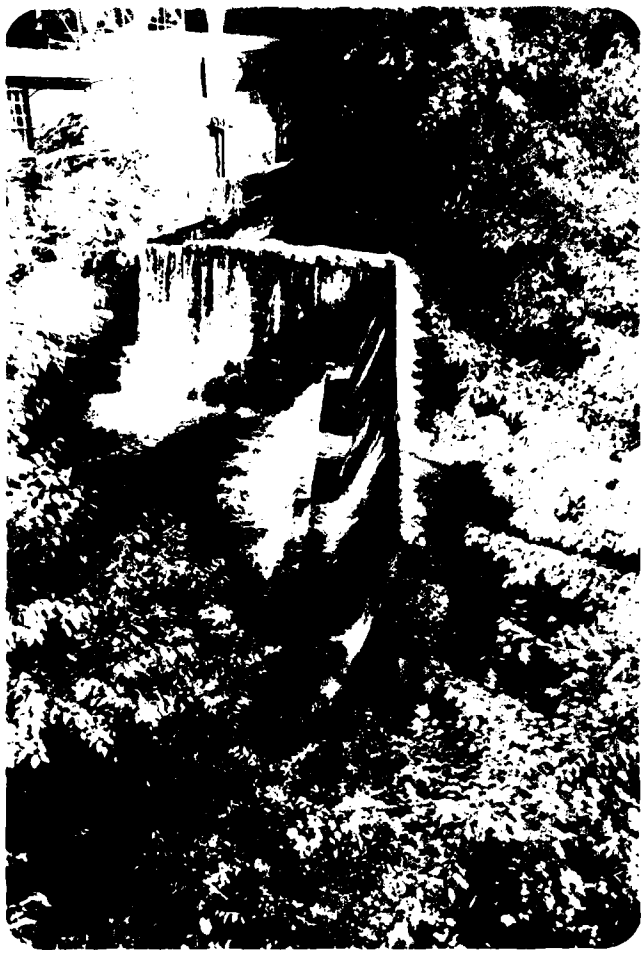
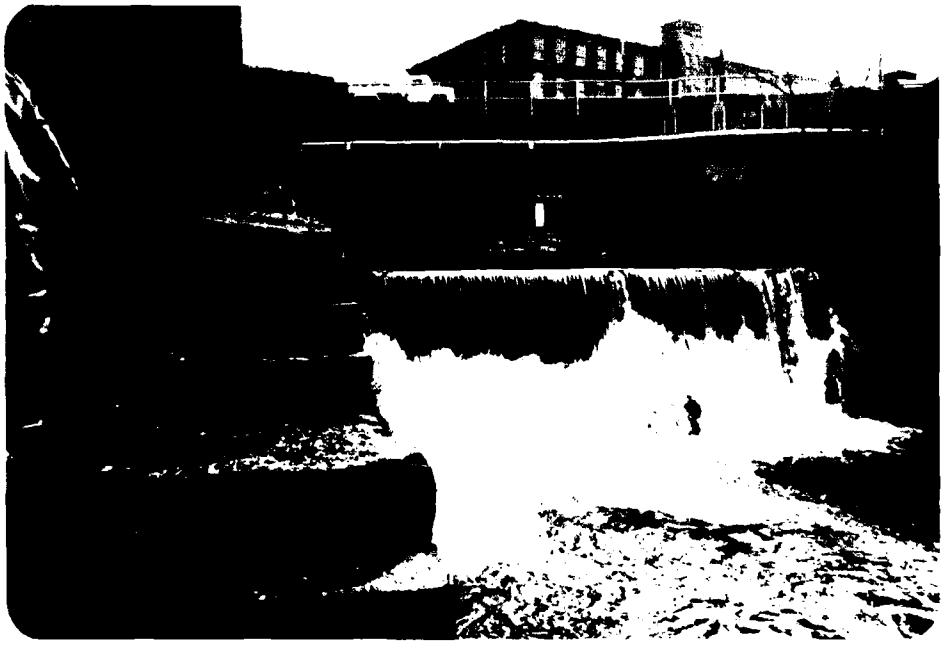
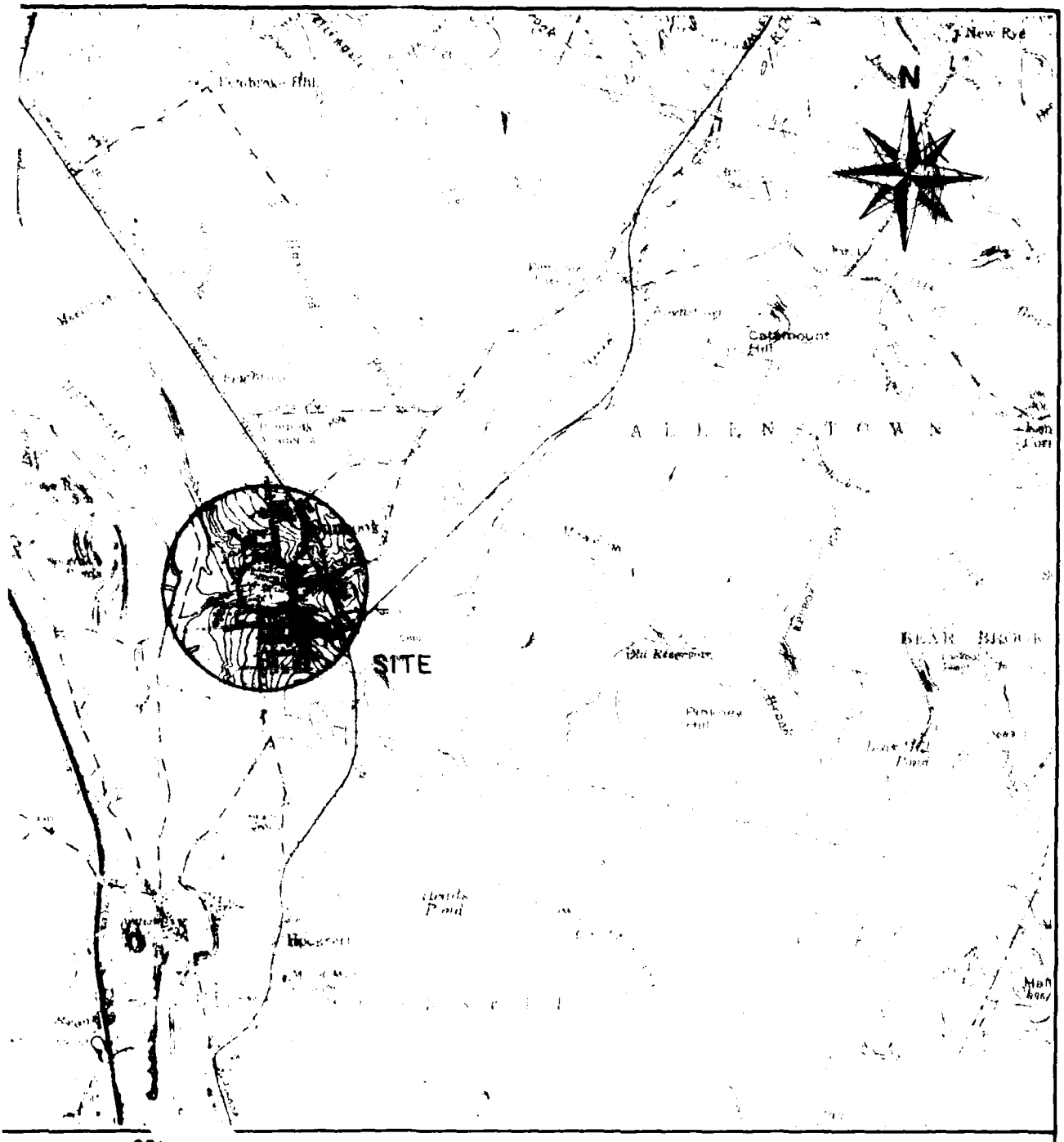


Overview of dam from left abutment



Overview from right side downstream showing upstream road bridge



– SCALE –

0 1/2 1 2 MILES

FROM: USGS SUNCOOK, N H
QUADRANGLE MAP

GOLDBERG, ZOINO, DUNNICLIFF & ASSOC., INC. GEOTECHNICAL CONSULTANTS NEWTON UPPER FALLS, MASS.	U.S. ARMY ENGINEER DIV. NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

LOCUS PLAN

FILE No. 2201

PEMBROKE DAM NEW HAMPSHIRE

SCALE	AS NOTED
DATE	JANUARY 1979

750 feet downstream of Pembroke Dam; about 3 houses at elevation 216.0 feet MSL below China Dam; a trestle carrying a sewer line across the Suncook below China Dam; and China Mill at elevation 205.5 feet MSL just before the confluence with the Merrimack River.

The sudden increase in flow caused by the failure of Pembroke Dam would increase the head at China Dam from 2.3 feet to 4.3 feet (elevation 230.1 MSL, still 2.7 feet below the top of the abutments). The increase would not cause flooding at any of the other locations of interest, which are all well above the flood wave which would be generated by dam failure.

As shown in Table 3 of the Corps of Engineers' "Recommended Guidelines," the appropriate Test Flood for a dam classified as SMALL in size with a LOW hazard potential would be between the 50-year flow and the 100-year flow. The ANCO Flood Insurance Study gives a 50-year flow of 12,190 cfs and a 100-year flow of 15,115 cfs. Since the hazard classification is on the low side of LOW, the 50-year flow of 12,190 cfs is appropriate for use as the Test Flood for this dam. The peak elevation created by the flow of 12,190 cfs would be 256.6 feet MSL, 12.4 feet above the spillway, and 8.4 feet above the lower abutment and 4.9 feet above the upper abutment.

This dam would be seriously overtopped by the Test Flood, which is the 50-year flow. Indeed, ANCO's 10-year flow of 7000 cfs would overtop the lower abutment by about 5.25 feet. However, it would appear from the hydraulics of this low head dam that higher flows would cause the dam to be submerged, and that downstream flows would not be greatly affected by failure of the dam. At low flows, dam failure would increase downstream flows, but they would remain below hazardous levels.

(f) Dam Failure Analysis

The peak outflow that would result from the failure of Pembroke Dam is estimated using the procedure suggested in the Corps of Engineers New England Division's April 1978 "Rule of Thumb Guidelines for Estimating Downstream Dam Failure Hydrographs," as clarified in a December 7, 1978 meeting at the Corps' Waltham office. Failure is assumed to occur with the water surface elevation at the top of the lower abutment, 4.0 feet above the spillway crest, at an elevation of 248.1 feet.

The discharge prior to failure with the water level at the top of the lower abutment, 4.0 feet above the spillway, would be 1850 cfs as determined from the Stage-Discharge curve developed and shown in Appendix D. This flow is significantly less than ANCO's estimated 10-year flow of 6990 cfs. The tailwater prior to failure would be 233.4 feet MSL, 10.7 feet below the spillway.

With a 30-foot gap opened in the spillway, dam failure would cause flow to increase by 2840 cfs to 4690 cfs. There are several areas along the Suncook downstream vulnerable to flooding, including about 5 houses at 239.0 feet MSL 650 feet downstream of the dam; China Dam

(d) Visual Observations

The approach channel upstream of the dam is narrow with steep banks on each side. The right bank consists of a high granite block wall. About fifty feet upstream of the dam, the river is crossed by the Main Street Bridge which has a clear span opening of about 70 feet and a low chord height of about 16.8 feet above the spillway crest.

Downstream of Pembroke Dam, the river immediately enters the pool of China Dam which is located about 800 feet downstream of Pembroke Dam. A built-up area on the right bank of the river in the vicinity of China Dam has about 5 homes located near elevation 239 feet upstream of the dam and about 3 homes near elevation 216 feet in the area below the dam. About 800 feet downstream of China Dam the river is crossed by a conduit bridge having a clear span of about 98 feet. China Mill is at an elevation of 205 feet above MSL slightly downstream of the bridge. Below this structure the floodplain of the river widens considerably before joining the Merrimack River another 1,400 feet further on.

(e) Test Flood Analysis

The hydrologic conditions of interest in this Phase I investigation are those required to assess the dam's overtopping potential and its ability to safely allow an appropriately large flood to pass. This requires using the discharge and storage characteristics of the structure to evaluate the impact of an appropriately sized Test Flood. None of the original hydraulic and hydrologic design records are available for use in this study.

Guidelines for establishing a recommended Test Flood based on the size and hazard classification of a dam are specified in the "Recommended Guidelines" of the Corps of Engineers. The impoundment of less than 1,000 acre-feet and the height of less than 40 feet classify this dam as a SMALL structure.

The appropriate hazard classification for this dam is LOW. Although the failure of Pembroke Dam would cause a one to two foot rise in downstream water surface, the surface would still be well below a hazardous level. It is unlikely that failure of Pembroke Dam would cause loss of life or serious economic losses.

SECTION 5 - HYDRAULICS/HYDROLOGY

5.1 Evaluation of Features

(a) General

Pembroke Dam is a run-of-the-river dam on the Suncook River at Suncook, New Hampshire. This dam is about 50 feet downstream of the Main Street Bridge over the Suncook River and about six-tenths of a mile above the river's confluence with the Merrimack River. The dam is a stone masonry gravity structure with two broad-crested spillways at right angles to each other having lengths of 20 and 57 feet.

(b) Available Data

Data sources available for Pembroke Dam include prior inventory and inspection reports. Much of the basic data for the dam is contained in the New Hampshire Water Control Commission's "Data on Dams in New Hampshire" (April 26, 1939); the New Hampshire Water Resources Board's "Inventory of Dams and Water Power Developments" (August 3, 1935), "Water Power Developments in New Hampshire" (January 28, 1948), and "Water Powers of New Hampshire" (July 10, 1942); and the Public Service Commission of New Hampshire's "Dam Record" (undated). Inspection reports dated June 5, 1918; June 14, 1950, and December 5, 1977 are available as are a 1939 sketch of the dam and related spillway capacity calculations. There are also several letters dated in 1978 in which the New Hampshire Water Resources Board attempts to identify the dam's owner.

More recent data includes a 1977 Flood Insurance Study by Anderson-Nichols and Company, Inc. (ANCO) which covers this portion of the Suncook River. This work includes 10, 50, 100 and 500-year peak inflows; cross-section data at various points on the Suncook River (including the dam and the bridge just upstream); and HEC-2 runs for the 10, 50, 100, 500-year flows.

(c) Experience Data

No records of flow or stage are known to be available for Pembroke Dam. China Dam 800 feet downstream of Pembroke Dam has a recorded peak flow of 12,100 cfs on March 19, 1936. (From USGS Water Supply Paper 798, "The Floods of March 1936.").

SECTION 4 - OPERATIONAL PROCEDURES

4.1 Procedures

There are no operational procedures for the dam.

4.2 Maintenance of Dam

No maintenance is performed on the dam.

4.3 Maintenance of Operating Facilities

No maintenance is performed on any of the dam's facilities. None of the gates are operational:

4.4 Description of Warning System

No formal warning system exists for this dam.

4.5 Evaluation

The dam's present POOR condition is a direct result of the lack of maintenance performed at the dam.

Some of the columns were founded on the crown of the penstocks which has resulted in permanent deflection of these conduits. It is not known whether this procedure had the approval of the local building inspector or other authority. The forebay wall has been patched with concrete where stones had previously been dislodged.

(3) Right Upstream Training Wall

The right training wall is in fair condition with the exception of minor joint erosion at the spillway crest elevation which is attributed to moisture intrusion which has been subjected to alternating freeze and thaw cycles and ice damage.

(4) Left Wing Wall

The dry stone masonry wing wall set on the left abutment is tightly constructed and is in good condition.

(5) Sluice Gates

Both sluice gates are inoperable. These gates are significantly deteriorated. The gate operating equipment has not been maintained and has deteriorated. The hand wheel has been removed from the left gate.

3.2 Evaluation

Pembroke Dam is in POOR condition. Seepage through the spillway and the building foundation at the right end of the dam are major concerns. Erosion at the left end of the spillway has been halted by the placement of the stone training wall upstream. The lack of maintenance of the dam and the operating facilities are the reasons for the dam's POOR condition.

SECTION 3 - VISUAL OBSERVATIONS

3.1 Findings

(a) General

Pembroke Dam is in POOR condition at the present time. The structure requires extensive maintenance to provide for its continued use.

(b) Dam

(1) Spillway

Seepage was observed at numerous locations through the open joints. The outlet tunnel located at the top of the stepped foundation discharges water at approximately 50 gpm. This appears to be a drain outlet, since there is no evidence of a control structure. A bricked up opening approximately 3 feet square is located above the drain outlet. Another bricked up opening approximately 6 feet wide and 8 feet high is located adjacent to the left abutment. There are two courses of squared stone blocks which extend approximately 3 feet above this brick. It is conceivable that this was the location of a former waste gate.

(2) Mill Building Foundation

This structure is in poor condition. Observations of the interior of this foundation revealed that seepage at a rate of 5 to 10 gpm was emanating from the corner of the foundation adjacent to the right end of the spillway. Seepage at the approximate rate of 10 to 20 gpm is occurring through the foundation located to the right of the right sluice gate. Seepage through the brick masonry was observed at numerous random locations. The timber sluice gates are partially rotted resulting in a high rate of seepage flowing into the chamber. Standing water is prevalent over the major portion of the base of this chamber.

Modifications were made to the original floor supports to provide support for heavy machinery loads. This was accompanied by setting intermediate columns. The building is presently occupied by a furniture making company.

SECTION 2 - ENGINEERING DATA

2.1 Design Records

The design of the dam is quite simple and incorporates no unusual features. No original design drawings or calculations are available.

2.2 Construction Records

No construction records are available for this dam.

2.3 Operational Records

No operational records of value are available for this dam.

2.4 Evaluation of Data

(a) Availability

The lack of any design or construction drawings is a significant shortcoming. Therefore, an unsatisfactory assessment for availability is warranted.

(b) Adequacy

The lack of in-depth engineering data does not permit a definitive review. Therefore, the adequacy of the dam cannot be assessed from the standpoint of reviewing design and construction data. This assessment is based primarily on the visual inspection, past performance, and sound engineering judgment.

(c) Validity

Since the observations of the inspection team generally confirm the information contained in the files of the New Hampshire Water Resources Board, a satisfactory evaluation for validity is indicated.

(4) U/S channel: Full width of river, river is narrow with steep banks

(5) D/S channel: Full width of river except for mill building at right side

(g) Regulating Outlets

See section 1.3 (b) (1).

(c) Elevation (ft. above MSL)

(1) Top of lower abutment: 248.1
Top of upper abutment: 251.6

(2) Maximum pool: 248.1

(3) Normal pool: 244.1

(4) Spillway crest: 244.1

(5) Streambed at centerline: 226.0

(6) Maximum tailwater: Unknown

(d) Reservoir

(1) Length - maximum pool: 1000 feet ±
normal pool: 500 feet ±

(2) Storage - maximum pool: 34 acre-feet ±
normal pool: 30 acre-feet ±

(3) Surface area - maximum pool: 2 acres ±
normal pool: 1 acre ±

(e) Dam

(1) Type: Stone masonry gravity dam on bedrock

(2) Length: 108 feet

(3) Height: 25.6 feet

(4) Top width: 4 feet ± at spillway

(5) Side slopes: Spillway U/S 3 horizontal to 12 vertical

(f) Spillway

(1) Type: Stone masonry gravity dam with a broad-crested weir

(2) Length of weir: Two sections at approximately right angles; 20 feet and 57 feet in length

(3) Crest elevation: 244.1

(f) Operator

At the present time no one operates the structure.

(g) Purpose of Dam

The dam was originally built to provide power for the mill located at the right side of the dam. No power is being generated presently.

(h) Design and Construction History

The recorded history of this dam is very meager and is limited to the fact that the dam was built in 1891 and altered in 1893. However, the nature of the alterations is not described in any of the available data. Power was generated at the site at least until 1948, but the generating equipment has since been removed.

(i) Normal Operational Procedures

There are no operational procedures for this dam.

1.3 Pertinent Data

(a) Drainage Area

The drainage area consists of 259 square miles of gently to steeply sloping terrain. Most of the area is forested with very little development.

(b) Discharge at Damsite

(1) Outlet Works

The outlet works at the dam are two sluice gates which supplied water to the 2 penstocks in the mill building. The water was used for power generation. The sluice gates are not operable.

(2) Maximum Flood at Damsite

The maximum flood at the damsite is not known. however, China Dam only 800 feet downstream has a recorded peak flow of 12,100 cfs in March 19, 1936.

(3) Spillway Capacity at Maximum Pool Elevation:

1848 cfs.

The upstream end wall of the original mill building has been reconstructed with a new brick masonry bearing wall whose foundation is approximately 6 feet downstream from the right end of the dam. Two 8 foot diameter riveted steel penstocks located within the building are connected to the sluice gate outlets. The steel penstocks are 10 feet in diameter at their ends. All power generating equipment has been removed. The interior of the foundation wall has been lined with brick set in mortar. A stone arch opening with approximately a 25 foot span is located approximately 100 feet downstream of the building forebay and is the remains of the building sluiceway.

The two sluice gates with timber stems cannot be observed. A steel trash rack is located in front of the sluice gates.

A wing wall extension of the left leg of the spillway which is approximately 15 feet long and founded on rock consists of granite slabs held together by vertical steel pins. The top of this wall is approximately 4 feet above the spillway crest.

(c) Size Classification

The dam's maximum impoundment of 34 acre-feet and height of 22 feet are below the 1,000 acre-foot and 40 foot height limits for the SMALL size category as defined in the "Recommended Guidelines."

(d) Hazard Potential Classification

In the event of a failure of Pembroke Dam the downstream water levels would rise approximately 1 to 2 feet. A rise in water levels of this amount would not result in significant economic loss or pose a threat of loss of life. For these reasons, a LOW hazard potential classification is warranted.

(e) Ownership

According to records obtained by the NHWRB the dam is owned by Thomas Hodgson and Sons, Inc. of Suncook, N.H. The firm is located on Canal Street in Suncook.

1.2 Description of Project

(a) Location

Pembroke Dam lies on the Suncook River and crosses the town lines of Pembroke and Allenstown, N.H. The dam is about 50 feet downstream from where the Main Street Bridge crosses the Suncook River and is about 0.6 miles upstream from the confluence of the Suncook and Merrimack Rivers. The portion of the USGS Suncook, N.H. quadrangle presented previously shows this locus. Figure 1 of Appendix B presents a detail of the site developed from the inspection visit and the quadrangle map.

(b) Description of Dam and Appurtenances

The dam and appurtenances consist of a dry squared stone masonry spillway and a mill building with abandoned power generating facilities. There are two sluice gate openings.

The spillway consists of two legs at approximately a 90° angle to each other. The shorter leg, running parallel to the flow of the river, ties into the mill building and is about 20 feet long. The longer leg of 57 feet ties into a bedrock outcrop which forms the left abutment. Both legs of the spillway have a stepped foundation. The steps start approximately 13 feet below the crest of the right leg and 10 feet below the crest of the left leg. An outlet tunnel approximately 18 inches high by 24 inches wide is located at the top of the stepped foundation midway on the left leg of the spillway. Two bricked up openings are located on the left leg of the spillway; one above the outlet tunnel and the other adjacent to the left abutment.

The building foundation, part of which forms the right end of the dam, consists of a combination of dry and cemented stone masonry. Two sluice gates are located in the upstream face of the foundation. The width of the building at this point is approximately 30 feet and skews upstream at approximately 75 degrees to the dam axis. Approximately 30 feet from the left end of the building a cemented, stone masonry wall turns upstream at about a 90° angle. The wall is approximately 75 feet long and extends to the highway right-of-way.

PHASE I INSPECTION REPORT

PEMBROKE DAM

SECTION 1

PROJECT INFORMATION

1.1 General

(a) Authority

Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Goldberg, Zoino, Dunnicliff & Associates, Inc. (GZD) has been retained by the New England Division to inspect and report on selected dams in the State of New Hampshire. Authorization and notice to proceed was issued to GZD under a letter of November 28, 1978 from Colonel Max B. Scheider, Corps of Engineers. Contract No. DACW 33-79-C-0013 has been assigned by the Corps of Engineers for this work.

(b) Purpose

(1) Perform technical inspection and evaluation of non-federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-federal interests.

(2) Encourage and prepare the states to initiate quickly effective dam safety programs for non-federal dams.

(3) Update, verify, and complete the National Inventory of Dams.

(c) Scope

The program provides for the inspection of non-federal dams in the high hazard potential category based upon location of the dams and those dams in the significant hazard potential category believed to represent an immediate danger based on condition of the dam.

SECTION 6 - STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

(a) Visual Observations

The field investigation revealed no significant displacement or distress which would warrant the preparation of structural stability calculations, based on assumed sectional properties and engineering factors.

There is seepage through open joints in the spillway, the mill building foundation and the partially rotted timber sluice gate at the mill building. The sluice gates are deteriorated and inoperable.

(b) Design and Construction Data

No plans or calculations of value to a stability assessment are available for this dam.

(c) Operating Record

No operating records are available for the dam. The dam has withstood overtopping on several occasions in the past.

(d) Post Construction Changes

The post construction changes that have been made have improved the stability of the dam.

(e) Seismic Stability

The dam is located in Seismic Zone No. 2 and, in accordance with recommended Phase I guidelines, does not warrant seismic analysis.

SECTION 7 - ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES

7.1 Dam Assessment

(a) Condition

The Pembroke Dam is in POOR condition at the present time.

(b) Adequacy of Information

The lack of in-depth engineering data does not permit a definitive review. Therefore, the adequacy of the dam cannot be assessed from the standpoint of reviewing design and construction data. This assessment is based primarily on the visual inspection, past performance, and sound engineering judgment.

(c) Urgency

The engineering studies and recommendations regarding the spillway seepage, foundation seepage, and condition of the sluice gates should be implemented by the owner within one year of receipt of the Phase I inspection Report.

(d) Need for Further Investigation

Additional investigations should be performed by the owner as outlined in paragraph 7.2.

7.2 Recommendations

It is recommended that the services of a registered professional engineer be retained to:

(1) Evaluate the source of the seepage in the mill foundation and bring the seepage under control.

(2) Evaluate rehabilitation or sealing the sluice gates and their operating mechanisms.

(3) Evaluate the foundation support system for the first floor of the building.

The findings of these studies should be implemented by the owner.

7.3 Remedial Measures

The recommended minimum remedial measures for this dam are to place a concrete face on all stone masonry and to bring the seepage through the spillway under control. Also institute a program of annual technical inspections.

7.4 Alternatives

One alternative to these recommendations would be to breach the dam.

APPENDIX A

VISUAL INSPECTION CHECKLIST

INSPECTION TEAM ORGANIZATION

Date: November 7, 1978

NH 00377
PEMBROKE DAM
Allenstown-Pembroke, New Hampshire
Suncook River
NHWRB

Weather: Overcast, 50°F ±

INSPECTION TEAM

Nicholas A. Campagna	Goldberg, Zoino, Dunnicliff & Associates, Inc. (GZD)	Team Captain
William S. Zoino	GZD	Foundations
Robert Minutoli	GZD	Soils
Andrew Christo	Andrew Christo Engineers (ACE)	Structural
Paul Razgha	ACE	Concrete
Richard Laramie	Resource Analysis, Inc.	Hydrology

The inspection team was accompanied by Mr. Pattu Kesavan of the New Hampshire Water Resources Board.

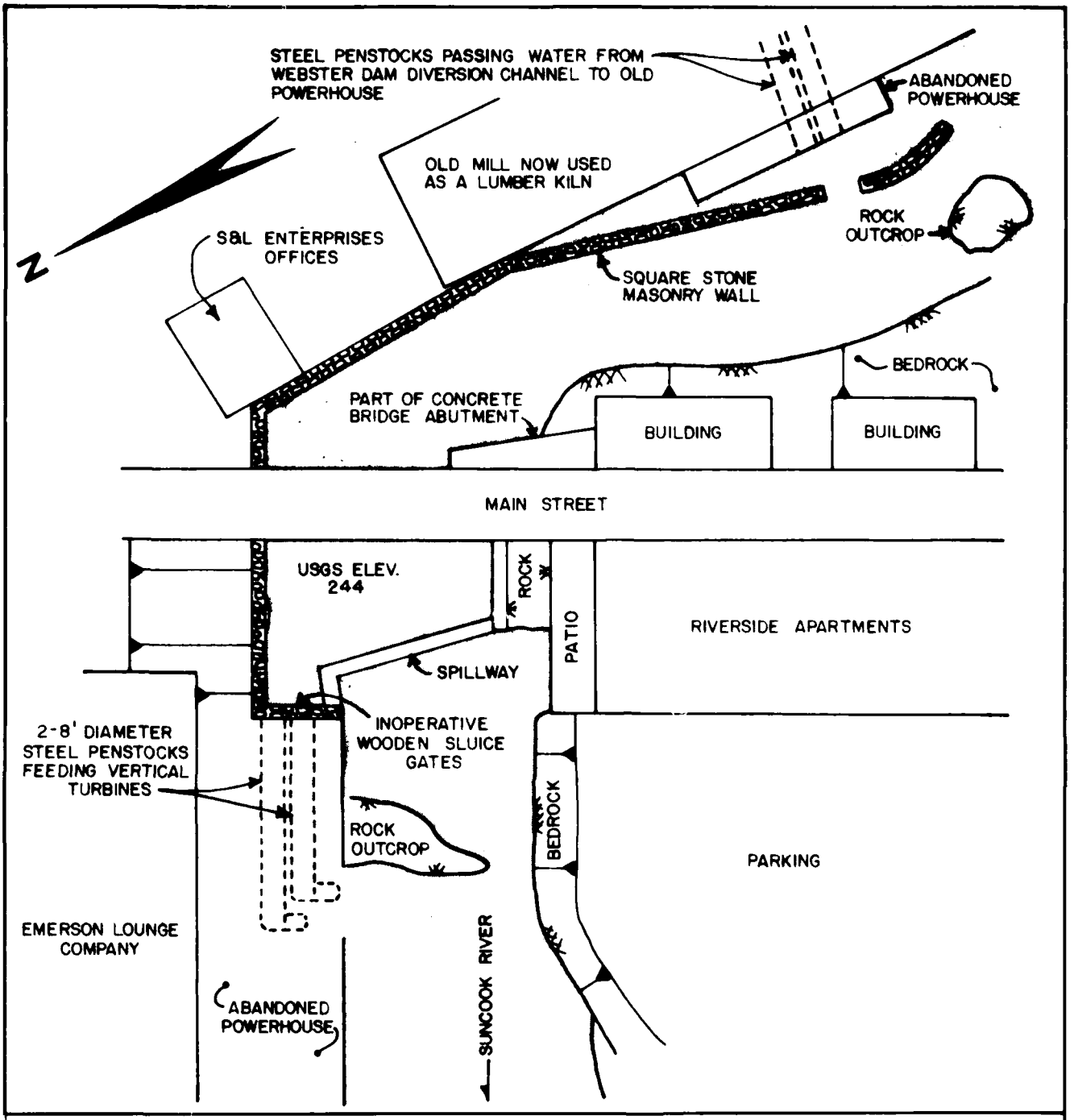
CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
DAM SUPERSTRUCTURE		
A. General		
Vertical alignment and movement	AC	No deficiencies noted
Horizontal alignment and movement		No deficiencies noted
B. Mill Building Foundation (Right Abutment)		Supporting columns founded on penstock; crowns deflected due to superimposed load
Seepage		Minor seepage prevalent throughout masonry wall foundation. Higher concentration of seepage located at the right side of the foundation and the interface with the right end of the spillway. The rates of seepage are 5 to 10 gpm and 10 to 20 gpm respectively
C. Right Training Wall		In good condition with the exception of minor joint erosion at spillway crest elevation
D. Left Abutment		Some erosion of bedrock
OUTLET WORKS		
A. Spillway		
Seepage	AC	Excessive random seepage through stone masonry joints. The outlet tunnel on left section of spillway discharges approximately 50 gpm

CHECK LISTS FOR VISUAL INSPECTION

AREA EVALUATED	BY	CONDITION & REMARKS
Structural condition	AC	No evidence of any distress
B. Sluice Gates	AC	Both gates are inoperable and deteriorated. Seepage flowing through and around gates
DOWNSTREAM CHANNEL		
Slope conditions	NAC	Steep slopes
Rock slides or falls		None noted
Control of debris		No debris noted
Tress overhanging the channel		None noted
Other obstructions		None noted
Existence of gages		None
RESERVOIR		
Shoreline		Stable, no slides noted
Sedimentation		None noted; some silting likely behind spillway
Upstream hazard areas in event of backflooding		Old mill building on right side
Changes in nature of watershed		None noted; already well developed commercial area along reservoir shore
OPERATION AND MAINTENANCE FEATURES		
Reservoir regulation		None presently exists
Maintenance	NAC	Considerable repairs and maintenance needed at dam

APPENDIX B



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GEOTECHNICAL CONSULTANTS
NEWTON UPPER FALLS, MASS.

U.S. ARMY ENGINEER DIV. NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

FIGURE 1

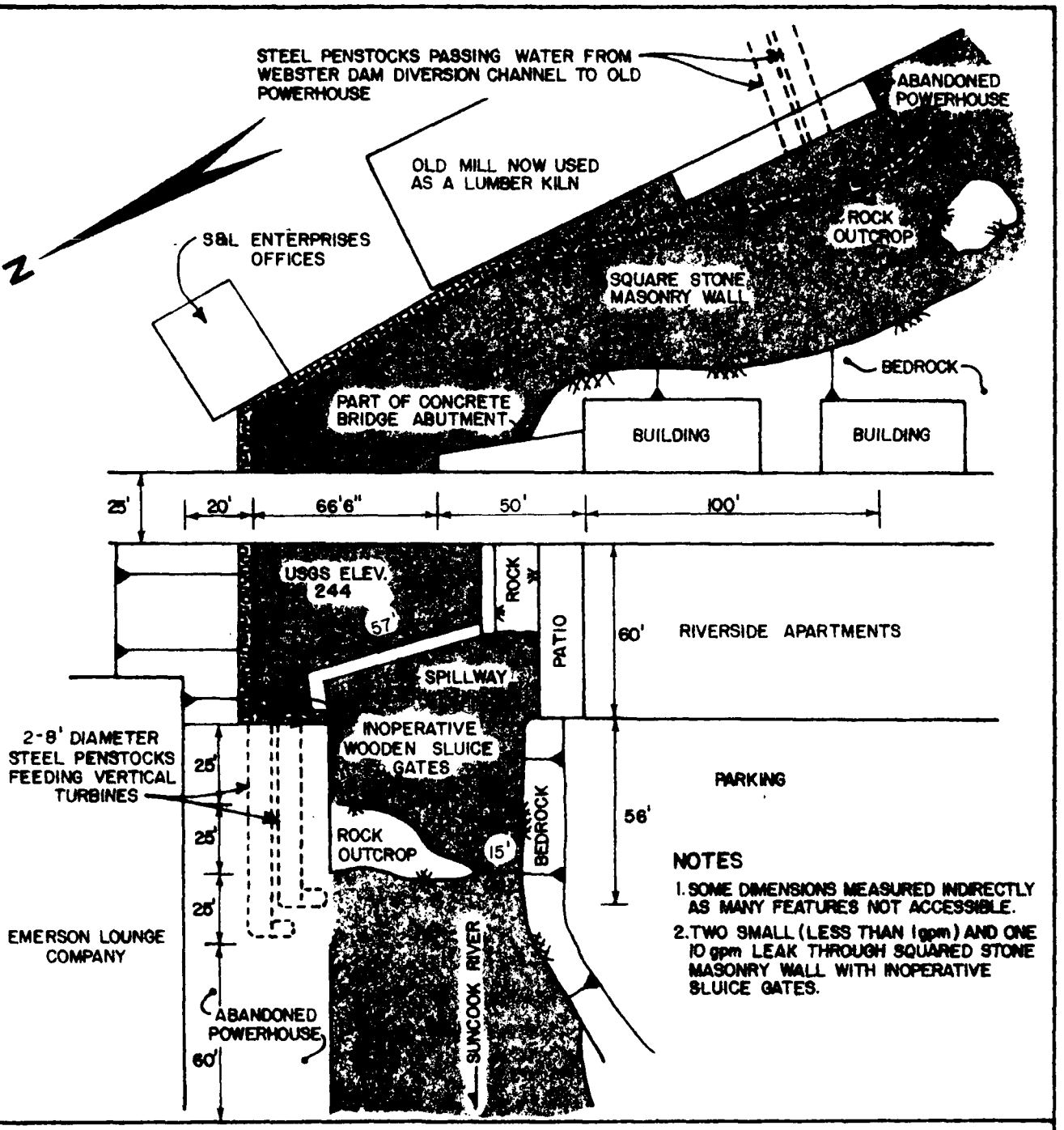
SITE PLAN

FILE No. 2201

PEMBROKE DAM

SCALE 1" = 50'

DATE NOVEMBER 1978



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NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

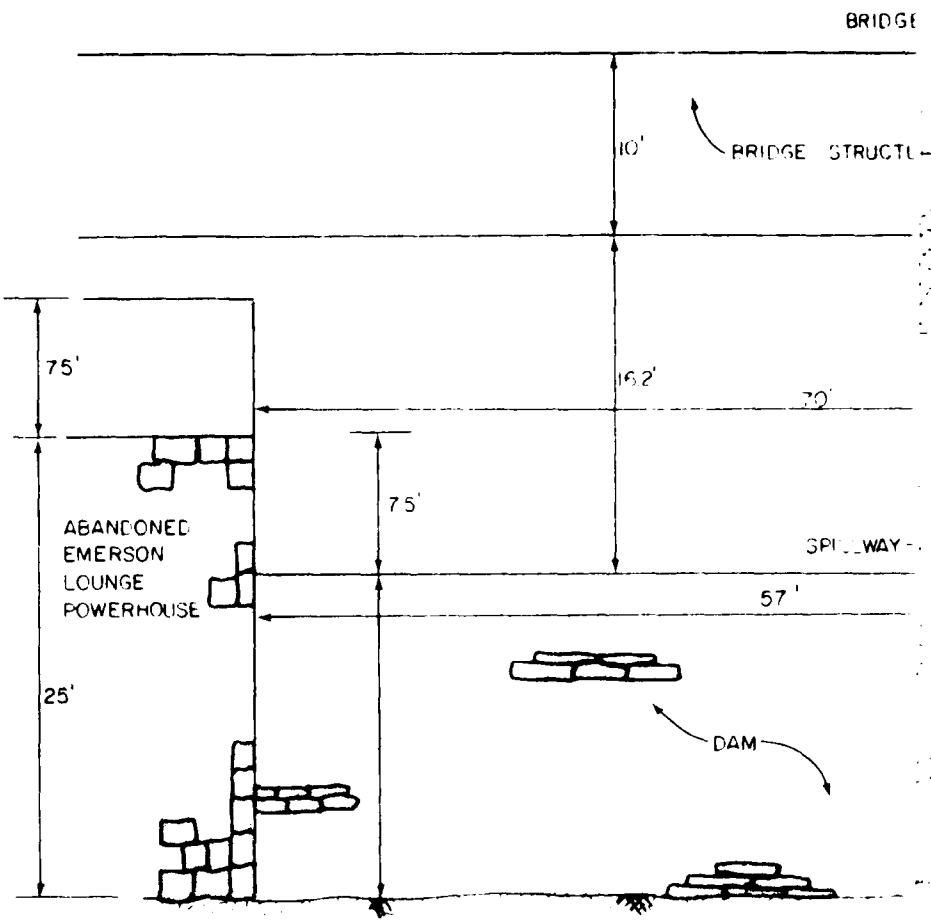
FIGURE 2

PLAN OF DAM

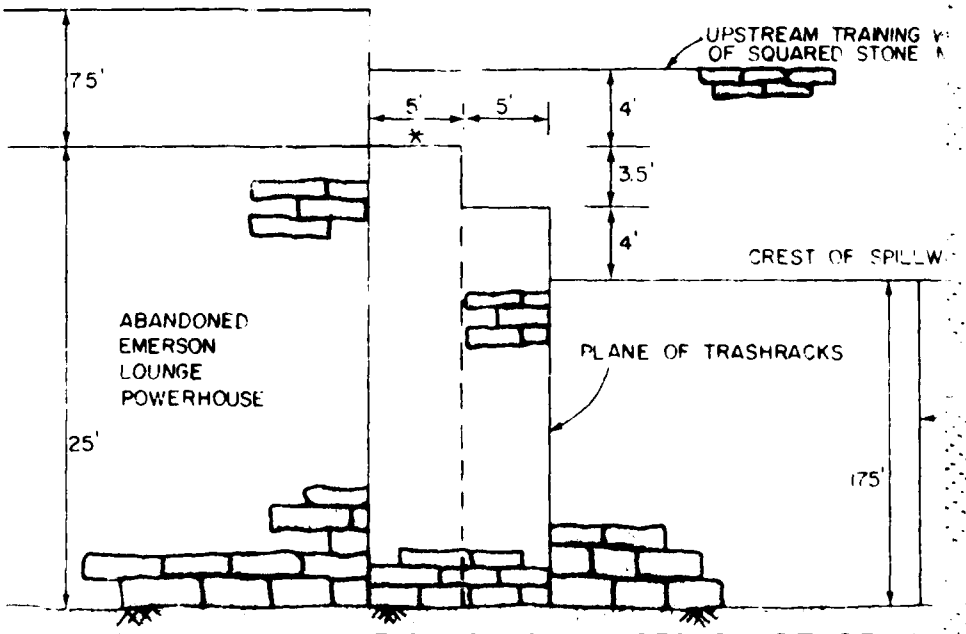
FILE No. 220

PEMBROKE DAM

SCALE	1" = 50'
DATE	NOVEMBER 1978

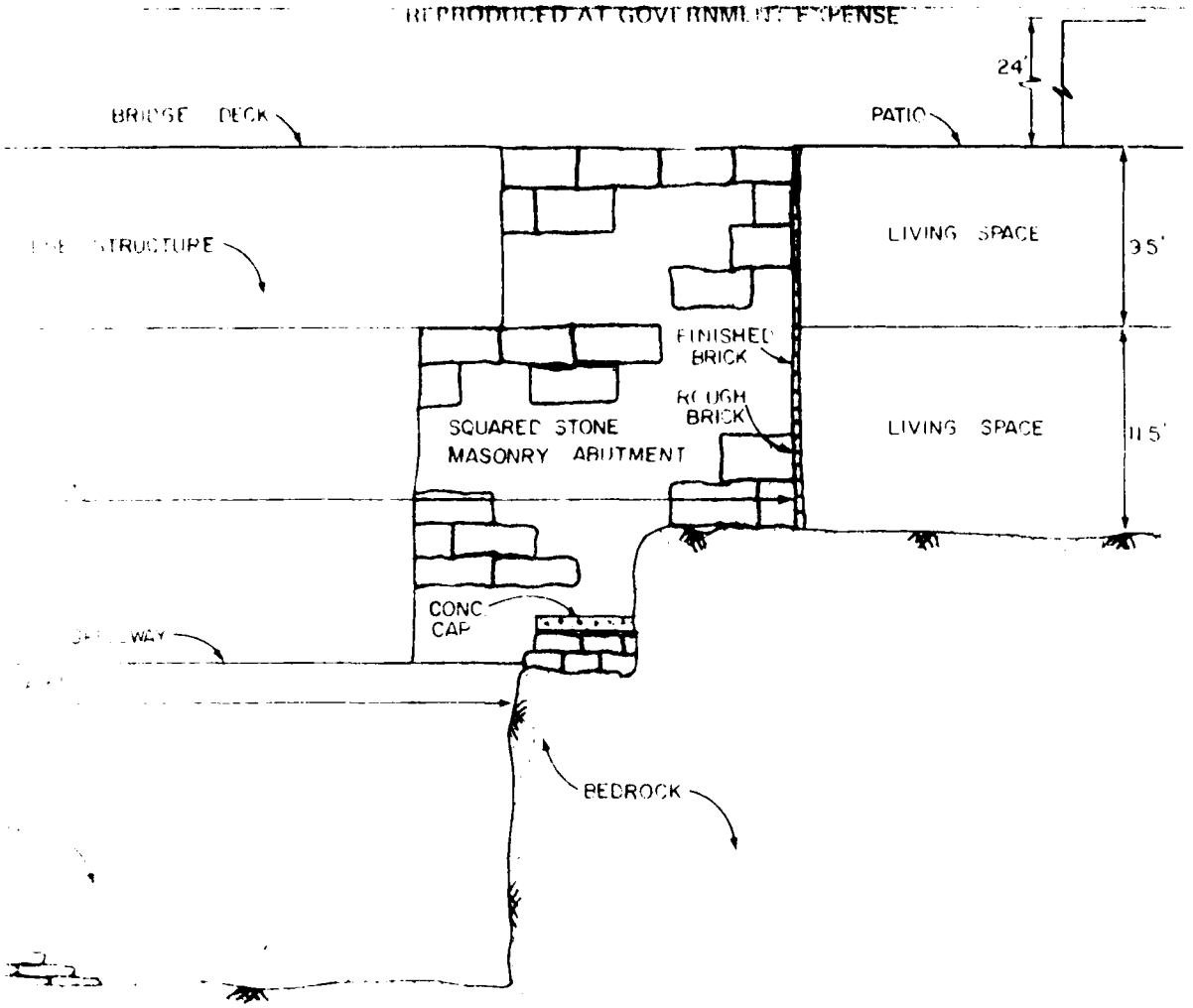


ELEVATION FROM DOW



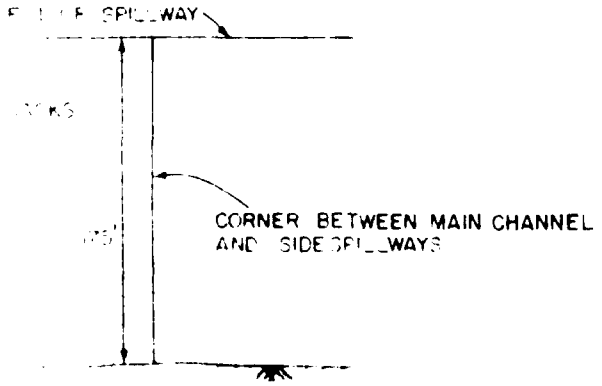
ELEVATION OF SIDE PORTION OF SPILL

* HIGH WATER 2 yrs AGO
HIGHEST IN 39 yrs ±



OM DOWNSTREAM

AM TRAINING WALL
RE STONE MASONRY



OF SPILLWAY

GOLDBERG, ZOINO, DUNNICLIFF & ASSOC., INC GEOTECHNICAL CONSULTANTS NEWTON UPPER FALLS, MASS	U.S. ARMY ENGINEER DIV. NEW E CORPS OF ENGINEERS WALTHAM, MASS

NATIONAL PROGRAM OF INSPECTION OF NON-FED

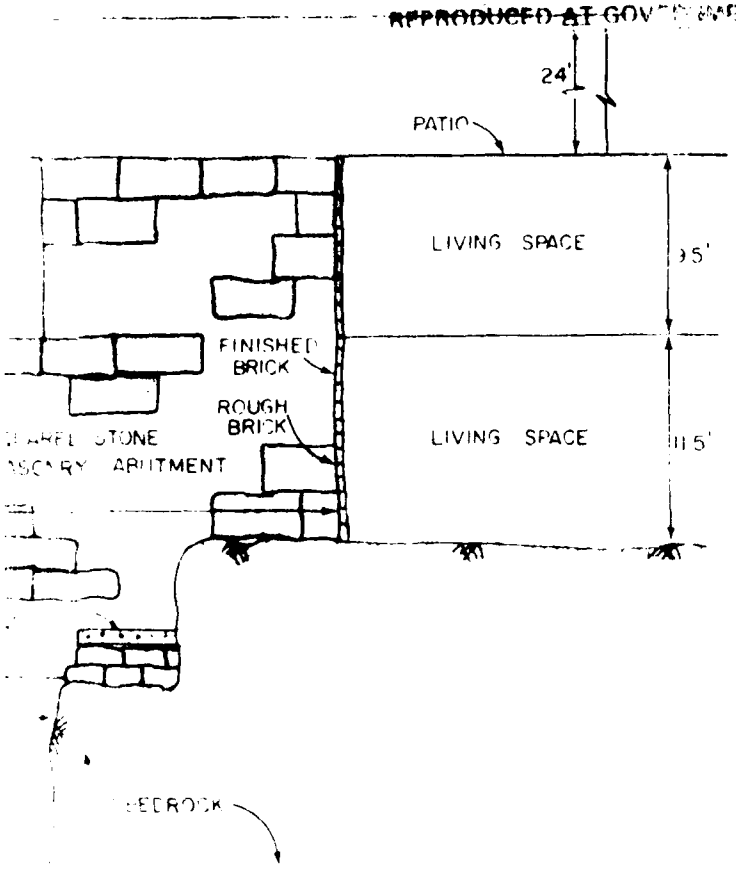
FIGURE 3

ELEVATION VIEWS

PEMBROKE DAM — NEW HAMPSHIRE

SCALE 1" = 10'

DATE



GOLDBERG, ZOINO, DUNNICLIFF & ASSOC., INC GEOTECHNICAL CONSULTANTS NEWTON UPPER FALLS, MASS	U.S. ARMY ENGINEER DIV NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

FIGURE 3

ELEVATION VIEWS

PEMBROKE DAM — NEW HAMPSHIRE

SCALE 1" = 10'

DATE

The New Hampshire Water Resources Board (NHWRB) located 37 Pleasant Street, Concord, N.H. 03301, maintains a compre-sive correspondence file for the dam. Some of the items luded in the file are:

(1) USGS "Report on Pembroke Dam" dated June 5, 1918.

(2) NHWRB "Inventory of Dams and Water Power Developments" dated August 3, 1935.

(3) The New Hampshire Water Control Commission's (NHWCC) "Data on Water Power Developments in New Hampshire."

(4) NHWCC "Data on Dams in New Hampshire" dated April 26, 1939.

(5) NHWRB questionnaires on "Water Powers in New Hampshire" dated July 10, 1942 and January 28, 1948.

(6) NHWCC inspection report dated June 1950.

(7) The Public Service Commission's of New Hampshire "Dam Record."

(8) NHWRB inspection report dated December 5, 1977.

(9) A January 9, 1978 letter from the NHWRB trying to identify the dam's owner and initiate repairs.

HEAD (FEET)	C1	DISCHARGE (CFS) TOTAL	LEFT BANK	RIGHT BANK	SPILLWAY
0.00	1.00	0	0	0	0
0.50	1.00	82	0	0	82
1.00	1.00	231	0	0	231
1.50	1.00	424	0	0	424
2.00	1.00	653	0	0	653
2.50	1.00	913	0	0	913
3.00	1.00	1200	0	0	1200
3.50	1.00	1513	0	0	1513
4.00	1.00	1848	0	0	1848
4.50	1.00	2217	5	6	2205
5.00	1.00	2616	15	18	2583
5.50	1.00	3040	28	33	2980
6.00	1.00	3488	42	51	3395
6.50	1.00	3959	59	71	3828
7.00	1.00	4450	78	94	4278
7.50	1.00	4961	98	118	4745
8.00	1.00	5505	125	153	5227
8.50	1.00	6079	157	197	5725
9.00	1.00	6678	193	248	6237
9.50	1.00	7300	233	303	6764
10.00	1.00	7945	276	364	7305
10.50	1.00	8610	321	429	7860
11.00	1.00	9295	369	498	8428
11.50	1.00	10000	420	571	9009
12.00	1.00	10723	473	648	9602
12.50	1.00	11465	528	728	10209
13.00	1.00	12224	586	811	10827
13.50	1.00	13000	645	897	11458
14.00	1.00	13794	706	987	12101
14.50	1.00	14603	770	1079	12755

P.8

DISCHARGE FROM PEMBROKE DAM AS A FUNCTION OF HEAD

HEAD (FEET)	C1	TOTAL	DISCHARGE (CFS) LEFT BANK	RIGHT BANK	SPILLWAY
0.00	1.00	0	0	0	0
0.25	1.00	29	0	0	29
0.50	1.00	82	0	0	82
0.75	1.00	150	0	0	150
1.00	1.00	231	0	0	231
1.25	1.00	323	0	0	323
1.50	1.00	424	0	0	424
1.75	1.00	535	0	0	535
2.00	1.00	653	0	0	653
2.25	1.00	780	0	0	780
2.50	1.00	913	0	0	913
2.75	1.00	1053	0	0	1053
3.00	1.00	1200	0	0	1200
3.25	1.00	1353	0	0	1353
3.50	1.00	1513	0	0	1513
3.75	1.00	1677	0	0	1677
4.00	1.00	1848	0	0	1848
4.25	1.00	2028	2	2	2024
4.50	1.00	2217	5	6	2205
4.75	1.00	2413	10	12	2391
5.00	1.00	2616	15	18	2583
5.25	1.00	2825	21	25	2779
5.50	1.00	3040	28	33	2980
5.75	1.00	3261	35	42	3185
6.00	1.00	3488	42	51	3395
6.25	1.00	3721	51	61	3609
6.50	1.00	3959	59	71	3828
6.75	1.00	4202	68	82	4051
7.00	1.00	4450	78	94	4278

P.7

```
460 C2=C1
470 T3=T1+T2+Q3
480 I1=I1+1
490 H1=1/1250*T3+234.44-244.1
500 IF H1>246.53-244.1 THEN 520
510 H1=1/1091*T3+232.68-244.1
520 IF H1<=0 THEN 590
530 H2=H-H1
540 IF H2/H>0.7 THEN 600
550 C1=1.063-0.04096*H/H2
560 Q3=Q3*C1/C2
570 IF I1<15 THEN 450
580 T3=T1+T2+Q3
590 RETURN
600 C1=1
610 RETURN
```


P.6

```
LIST
100 REM: STAGE DISCHARGE PROGRAM FOR PEMBROKE DAM, JOB 165
110 REM: ON TAPE 10, FILE 59
120 C1=1
130 PAGE
140 PRINT "DISCHARGE FROM PEMBROKE DAM AS A FUNCTION OF HEAD"
150 PRINT USING 160:
160 IMAGE /  2T"HEAD"30T"DISCHARGE"
170 PRINT USING 180:
180 IMAGE 1T"(FEET)"32T"(CFS)"
190 PRINT USING 200:
200 IMAGE 15T"C1"5X"TOTAL"5X"LEFT BANK"5X"RIGHT BANK"5X "SPILLWAY"
210 FOR H=0 TO 14.5 STEP 0.5
220 Q1=0
230 Q2=0
240 Q4=0
250 Q5=0
260 Q3=3*77*H↑1.5
270 IF H<=4 THEN 350
290 Q2=3*5*(H-4)↑1.5
300 Q4=3*6*(H-4)↑1.5
310 IF H<=7.5 THEN 350
320 Q1=2.8*5*(H-7.5)↑1.5
330 Q5=2.8*9*(H-7.5)↑1.5
350 T1=Q1+Q2
360 T2=Q5+Q4
370 T3=T1+T2+Q3
380 GOSUB 430
390 PRINT USING 400:H,C1,T3,T1,T2,Q3
400 IMAGE 1T,2D.2D,8D.2D,10D,12D,15D,14D
410 NEXT H
420 END
430 C1=1
440 I1=0
450 Q3=C1*3*77*H↑1.5
```

for $H_1 < 246.53 - 244.1 \rightarrow H_1 < 2.43$

$$H_1 = \frac{1}{1091} Q + 232.68 - 244.1 = \frac{1}{1092} Q - 11.42$$

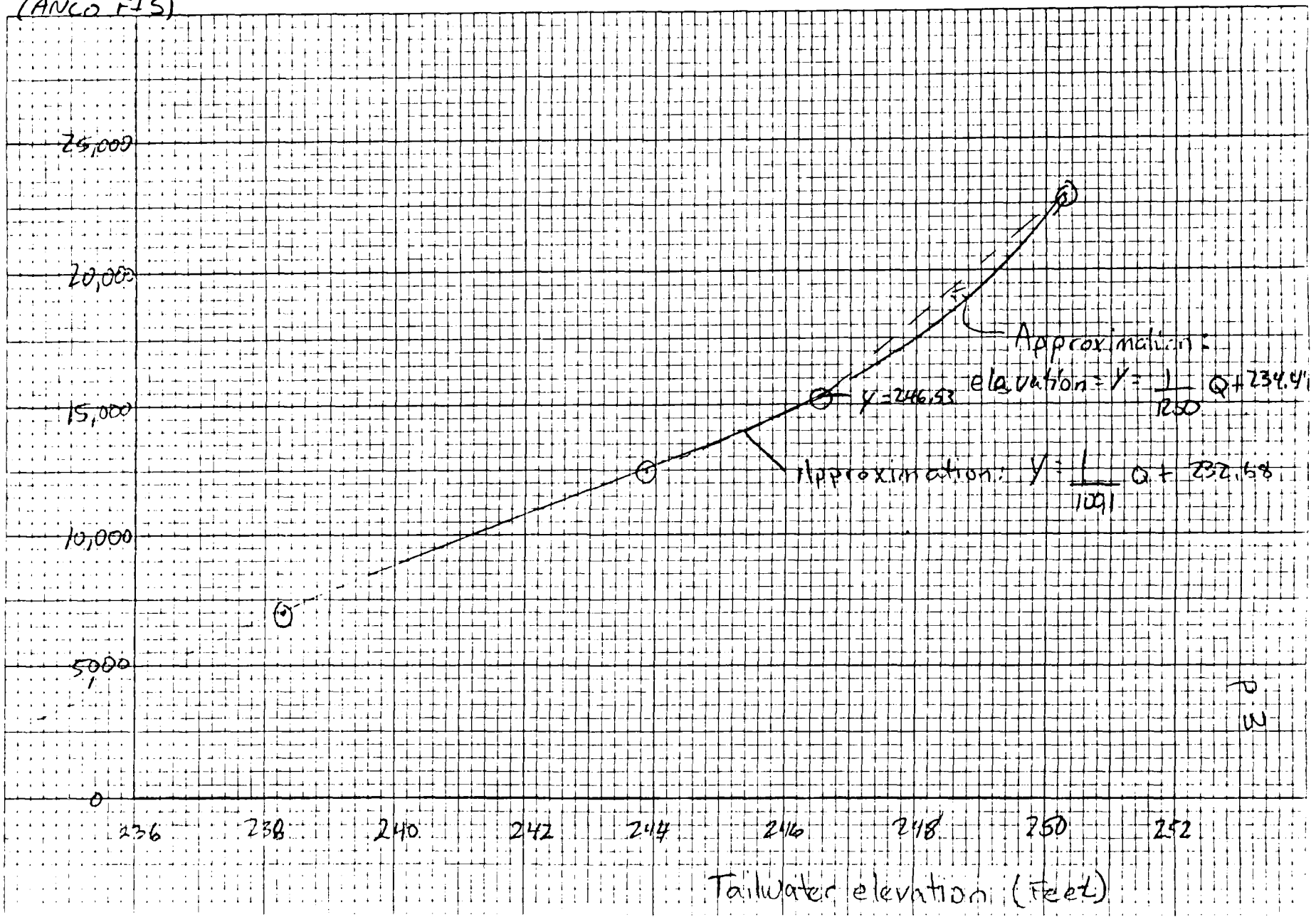
for $H_1 > 2.43$

$$H_1 = \frac{1}{1250} Q + 234.44 - 244.1 = \frac{1}{1250} Q - 9.66$$

see p.3

If $H_1 > 0$, the reduction factor applies. A BASIC subroutine to calculate the reduction factor (C1) is in Lines 430-620 of the Stage-Discharge calculation program which follows on pp. 5-9.

Tailwater at Pembroke Dam
(ANCO FIS)



for $h = 4.0$ to 7.5

$Q_2 = 3.0(5)(h-4.0)^{3/2}$

$Q_4 = 3.0(6)(h-4.0)^{3/2}$

all others unchanged

for $h = 7.5$ to 15.0

$Q_1 = 2.8(5)(h-7.5)^{3/2}$

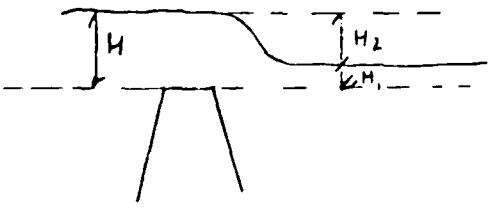
$Q_5 = 2.8(9)(h-7.5)^{3/2}$

all others unchanged

for broad-crested earth weir, $C = 2.8$

Tailwater Submergence:

At high flows the tailwater from the Suncook River submerges the spillway at Pembroke Dam. This tailwater submergence reduces flow over the spillway. The Bureau of Reclamations Design of Small Dams, Figure 254 gives a plot of reduction factor vs. H_2/H, with H_2 & H described in the sketch below:



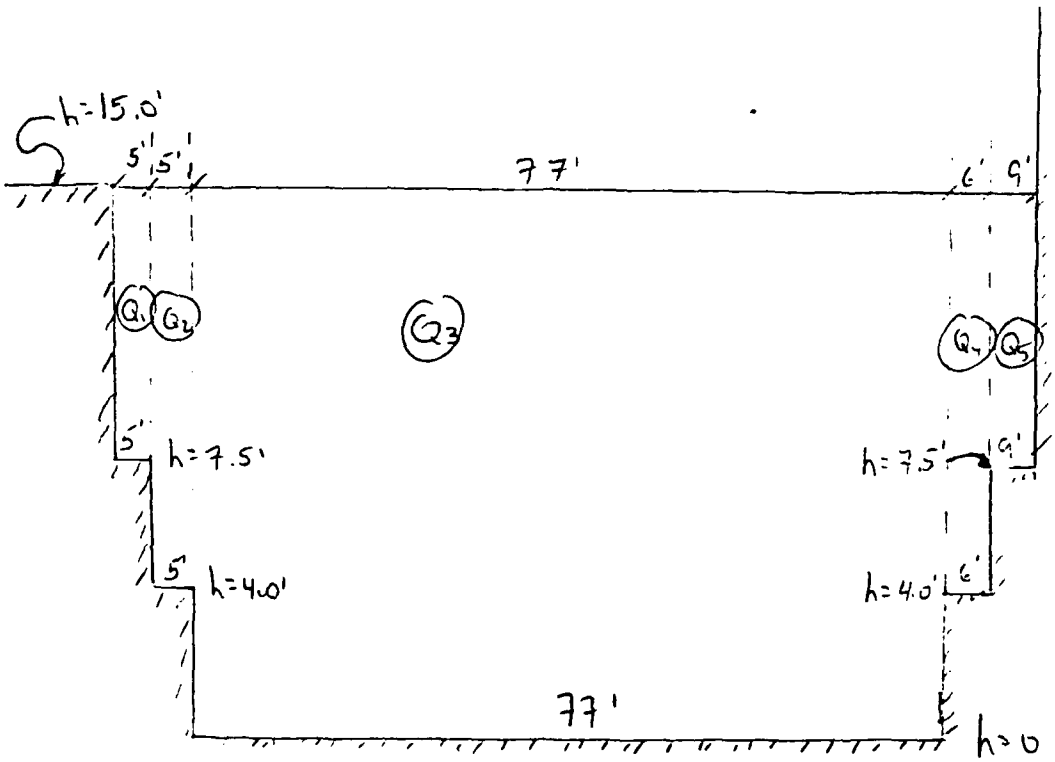
The relation ship in Figure 254 for H_2/H 7.7 gives no reduction in flow. for $.15 \leq H_2/H \leq .7$:

C_1 = reduction factor = $1.063 - .04096\left(\frac{1}{H_2/H_1}\right) = 1.063 - .04096\left(\frac{H_1}{H_2}\right)$

H_1 is taken from a linear estimate based on HEC-2 runs (see plot p.3).

Stage- Discharge Curve

The information used to establish the cross-section at Pembroke Dam was obtained from field notes, old plans, and ANCO FIS survey notes.



h=0 at Spillway crest (244.1 Ft. MSL)
no operable gates

for h=0 to 4.0

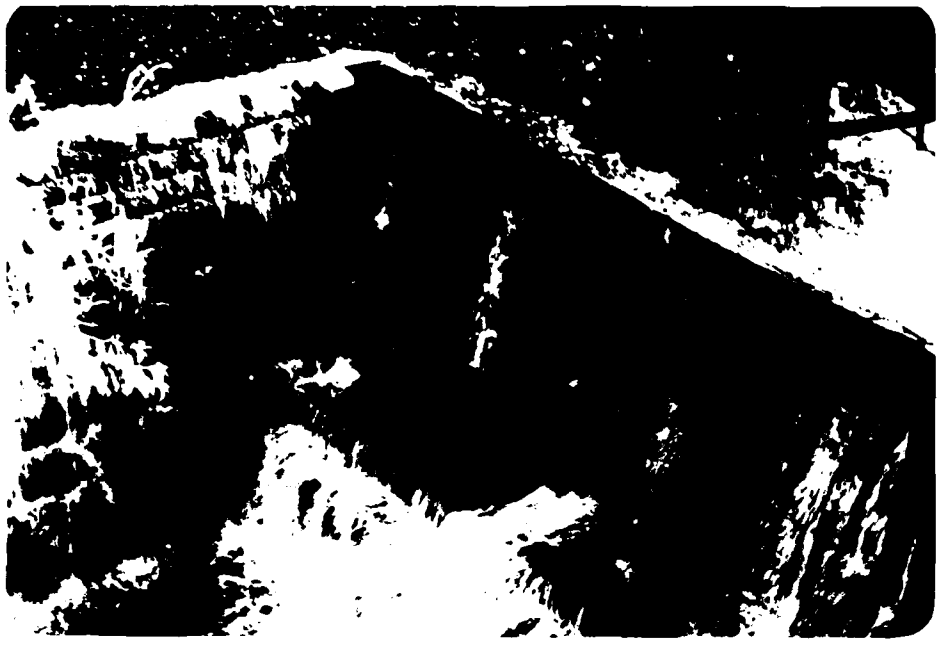
$$Q_3 = 3.0(77)\,h^{3/2}$$

$$Q_1 = Q_2 = Q_4 = Q_5 = 0$$

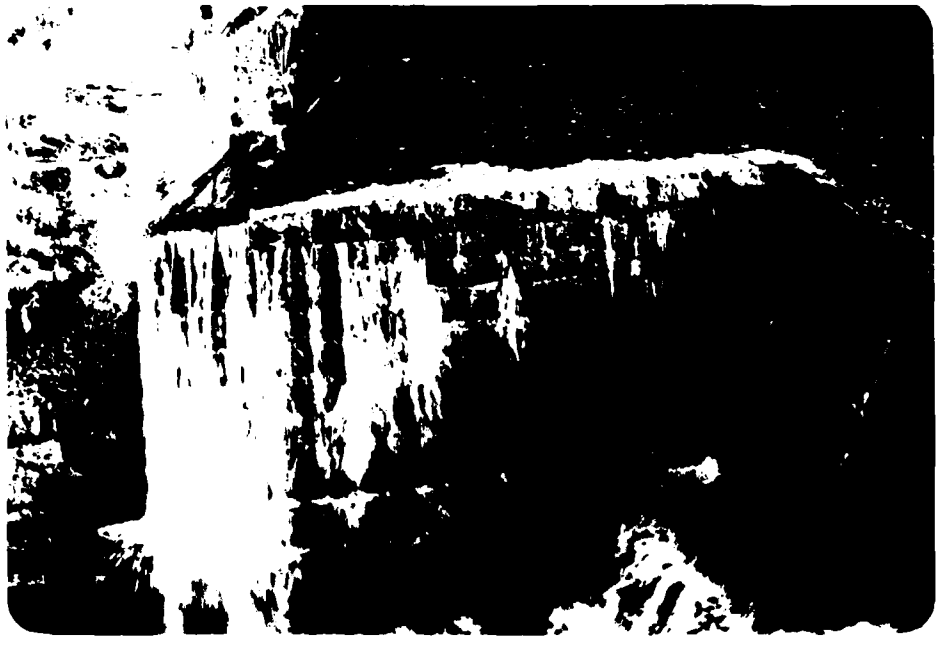
for broad-crested concrete weir, C=3.0

APPENDIX D

HYDROLOGIC/HYDRAULIC COMPUTATIONS



5. View from downstream left side showing leakage through squared stone masonry and unidentified rectangular outlet



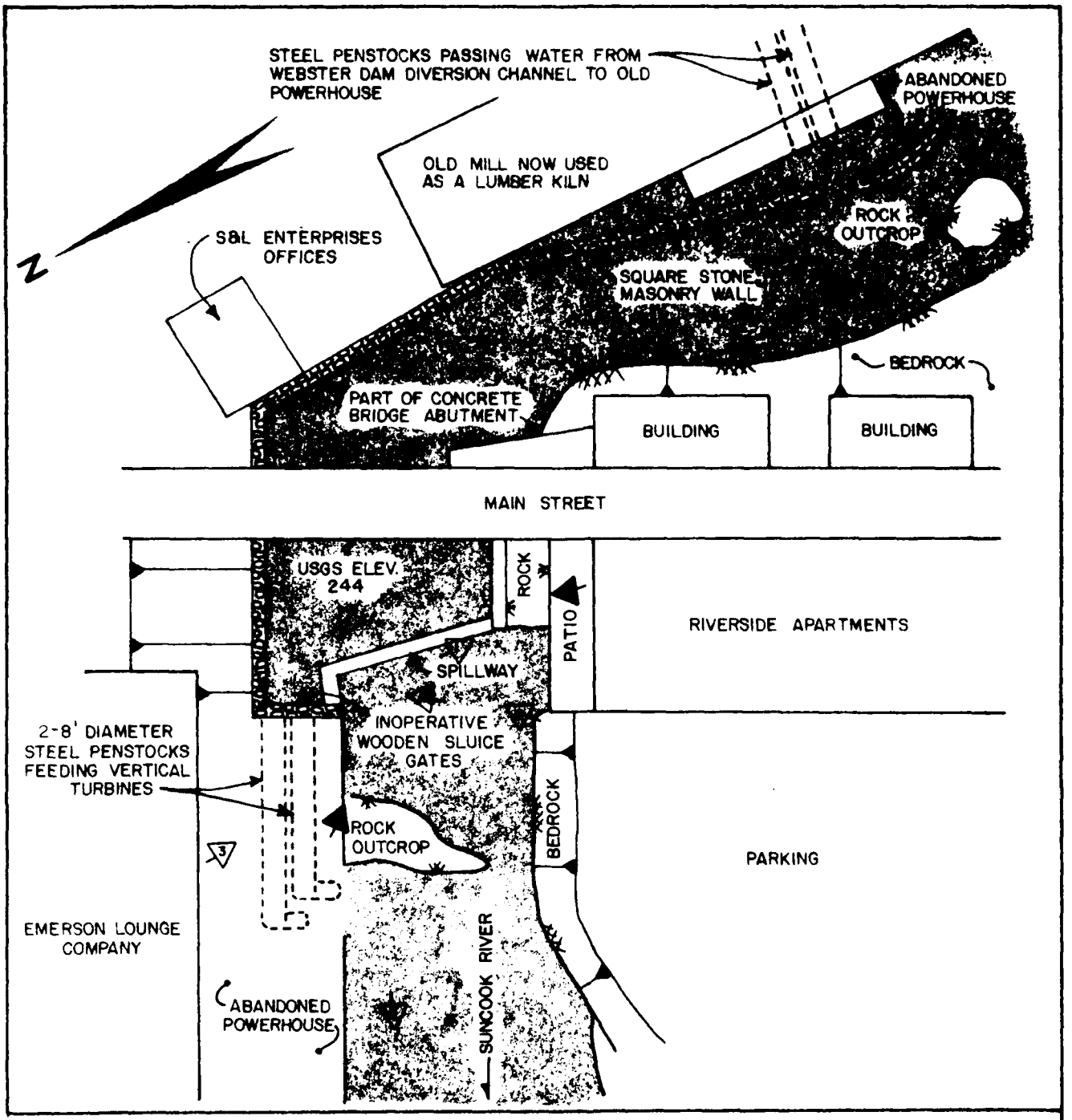
6. Detail of above photo highlighting leakage through dam

3. View from inside old mill building showing flow through holes in old penstock

4. View from left side showing old intake for power plant

1. View of left abutment from right side showing erosion of rock

2. View of downstream channel show[illegible] China Dam



▶ OVERVIEW

▷ APPENDIX C

GOLDBERG, ZOINO, DUNNICLIFF & ASSOC., INC
GEOTECHNICAL CONSULTANTS
NEWTON UPPER FALLS, MASS

U.S. ARMY ENGINEER DIV. NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

NATIONAL PROGRAM OF INSPECTION OF NON-FED. DAMS

LOCATION AND ORIENTATION OF PHOTOS

FILE No. 220

PEMBROKE DAM

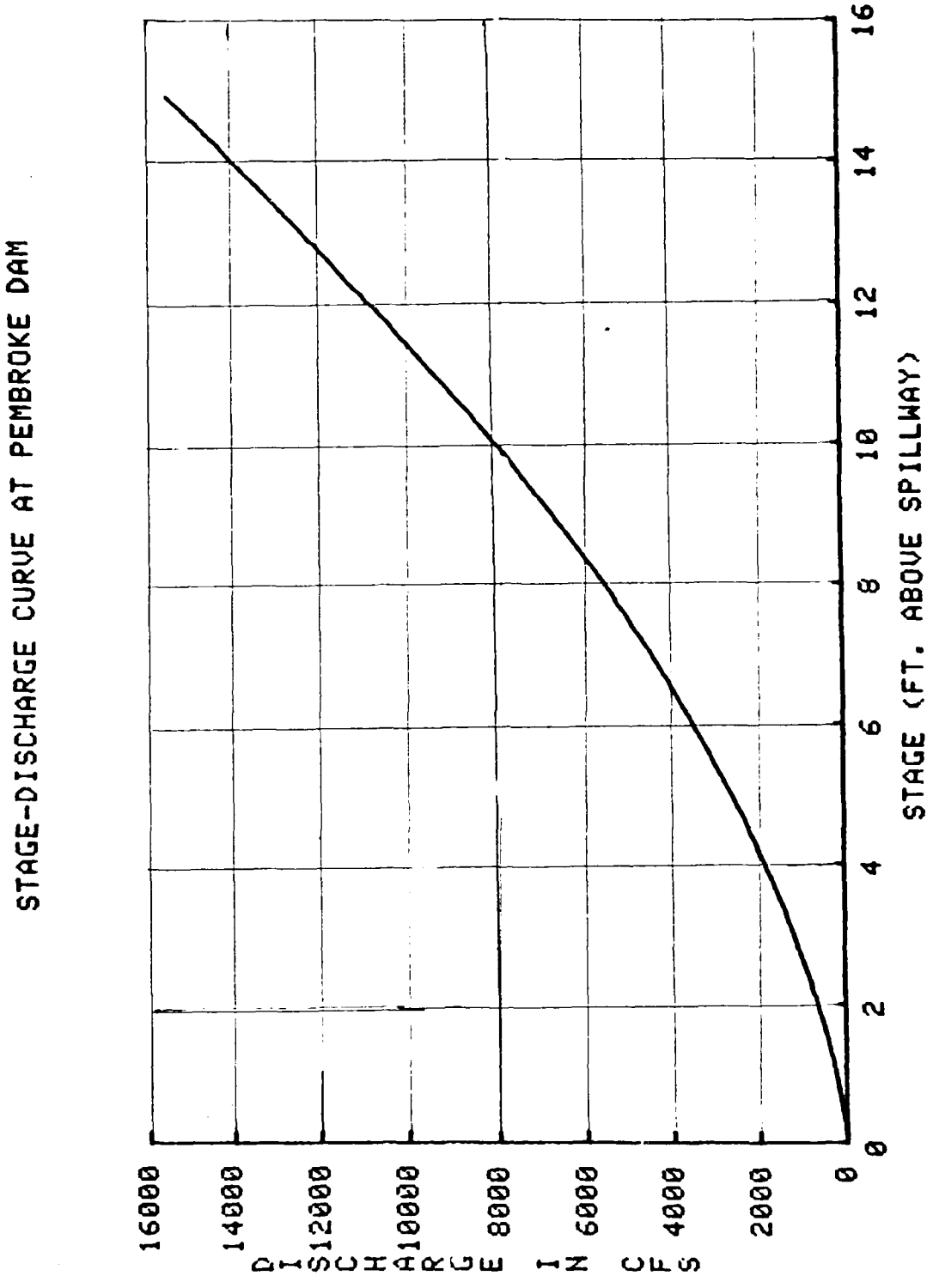
SCALE 1" = 50'

DATE NOVEMBER 1978

APPENDIX C

SELECTED PHOTOGRAPHS

P.9


STAGE-DISCHARGE CURVE AT PEMBROKE DAM
DISCHARGE IN CFS
16000
14000
12000
10000
8000
6000
4000
2000
0
0
2
4
6
8
10
12
14
16
STAGE (FT. ABOVE SPILLWAY)

DAM FAILURE ANALYSIS

Assume that the dam fails when the water surface elevation reaches the abutments, at h=4.0 (elevation 248.1). From the stage-discharge curve, this would require a discharge of 1850 cfs. The tailwater elevation curve indicates that this flow would create a tailwater elevation of about 233.4' MSL (linear extrapolation)

Peak failure outflow = Normal outflow + Breach outflow

Normal outflow = 1850 cfs

Breach outflow = $Q_{p_1} = \frac{8}{27} W_b \sqrt{g} (y_o)^{3/2}$

y_o = height of water surface above tailwater = 248.1 - 233.4 = 14.7

W_b = width of breach $\leq .4$ (width of span)

$= .4(77) \simeq 30'$

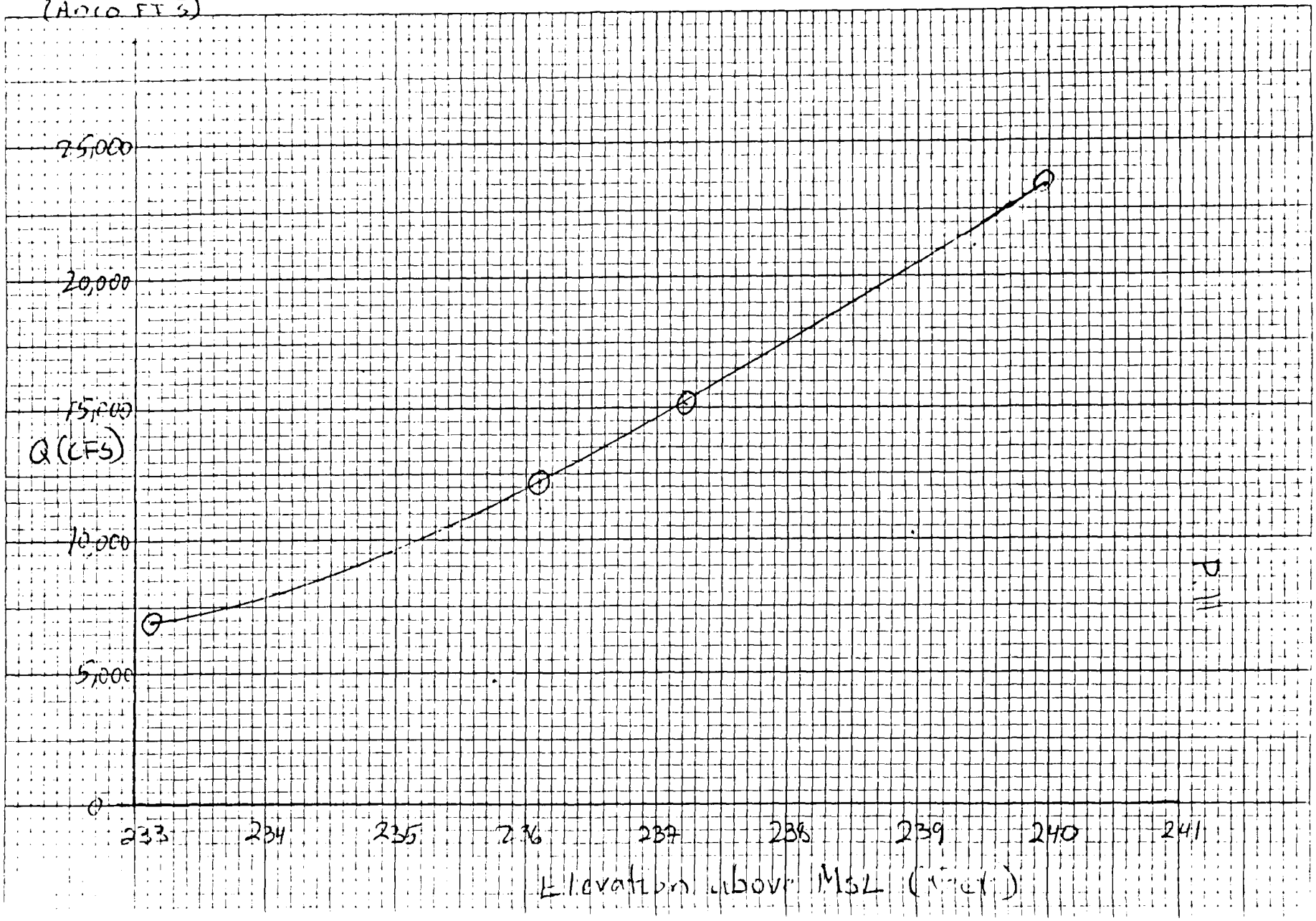
$Q_{p_1} = \frac{8}{27} (30) \sqrt{g} (14.7)^{3/2} = 2840$ cfs

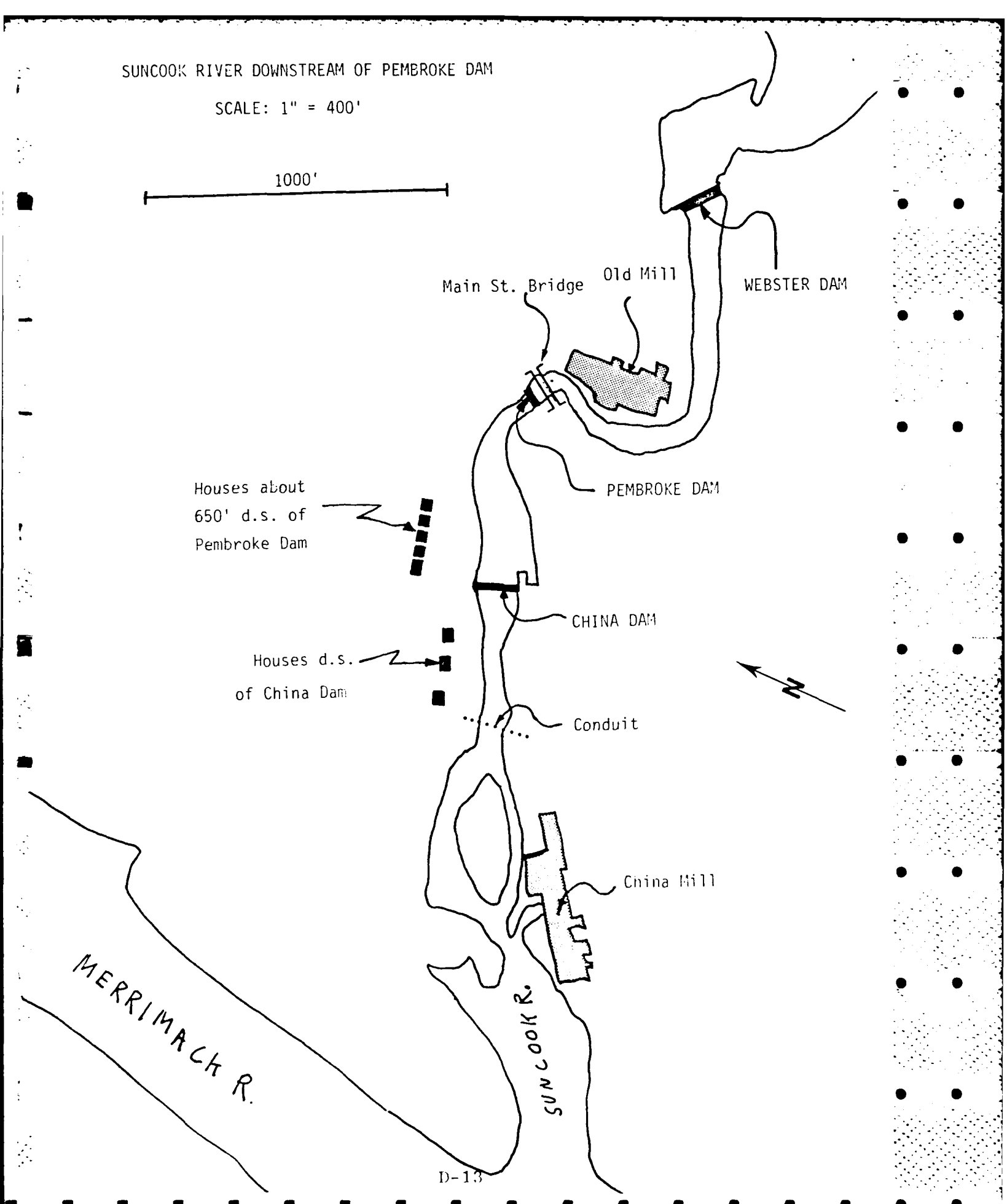
Peak Failure outflow = 1850 + 2840 = 4690 cfs

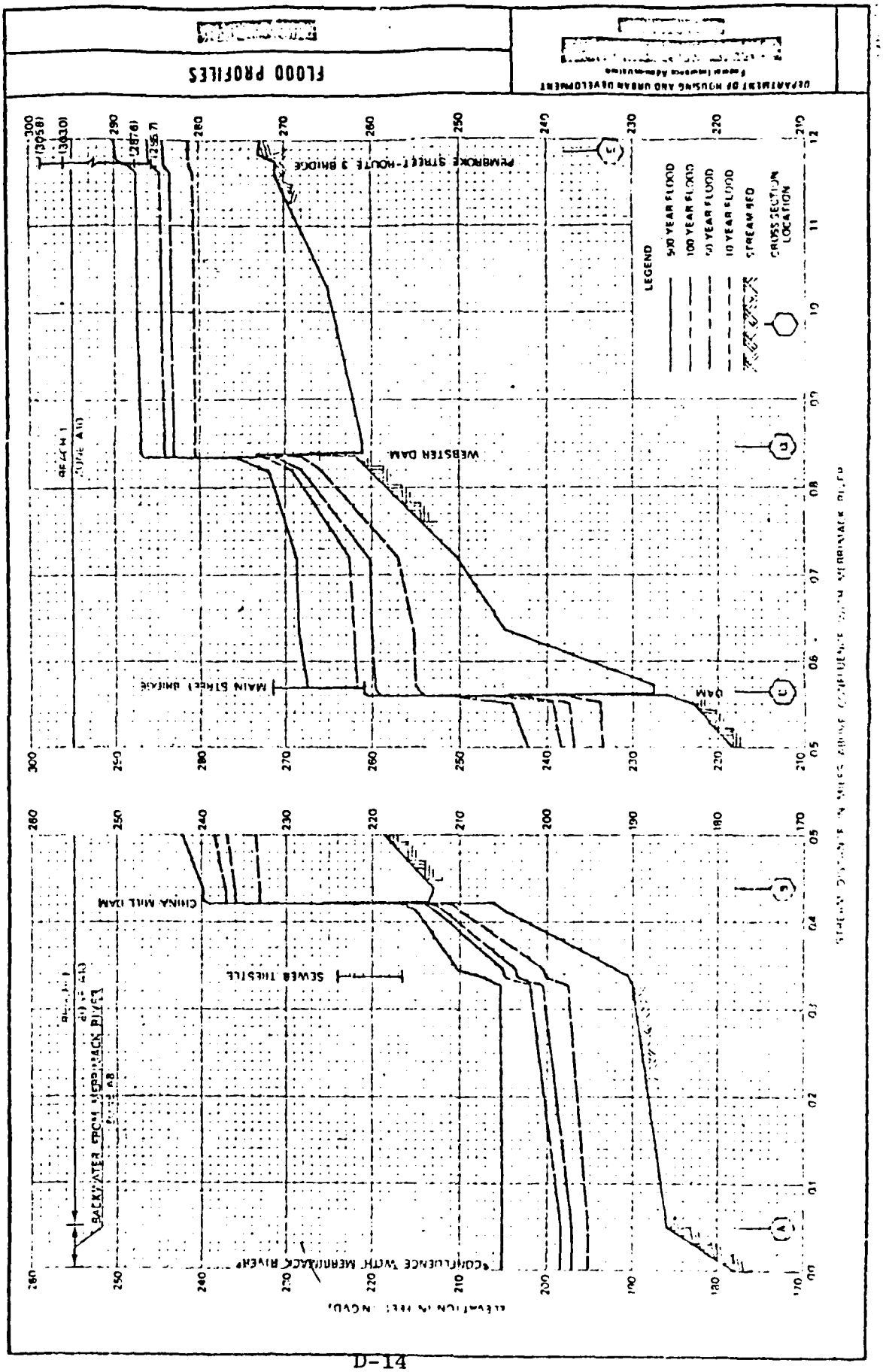
Due to the limited storage available downstream we will assume negligible attenuation of this peak down river. P. 12 shows the path of the Suncook River below Pembroke Dam. P. 13 and 14 show profiles of the river.

The 1st downstream location which might be affected by dam failure is a group of houses 650' downstream of the dam at 216' MSL. The Discharge-Elevation curve for the Suncook River at these houses is shown on p. 11. Note that the lowest discharge shown, 7000 cfs, requires a water surface elevation of 233.2' MSL - the peak failure outflow of 4690 cfs should generate a water surface below this, and well below the houses.

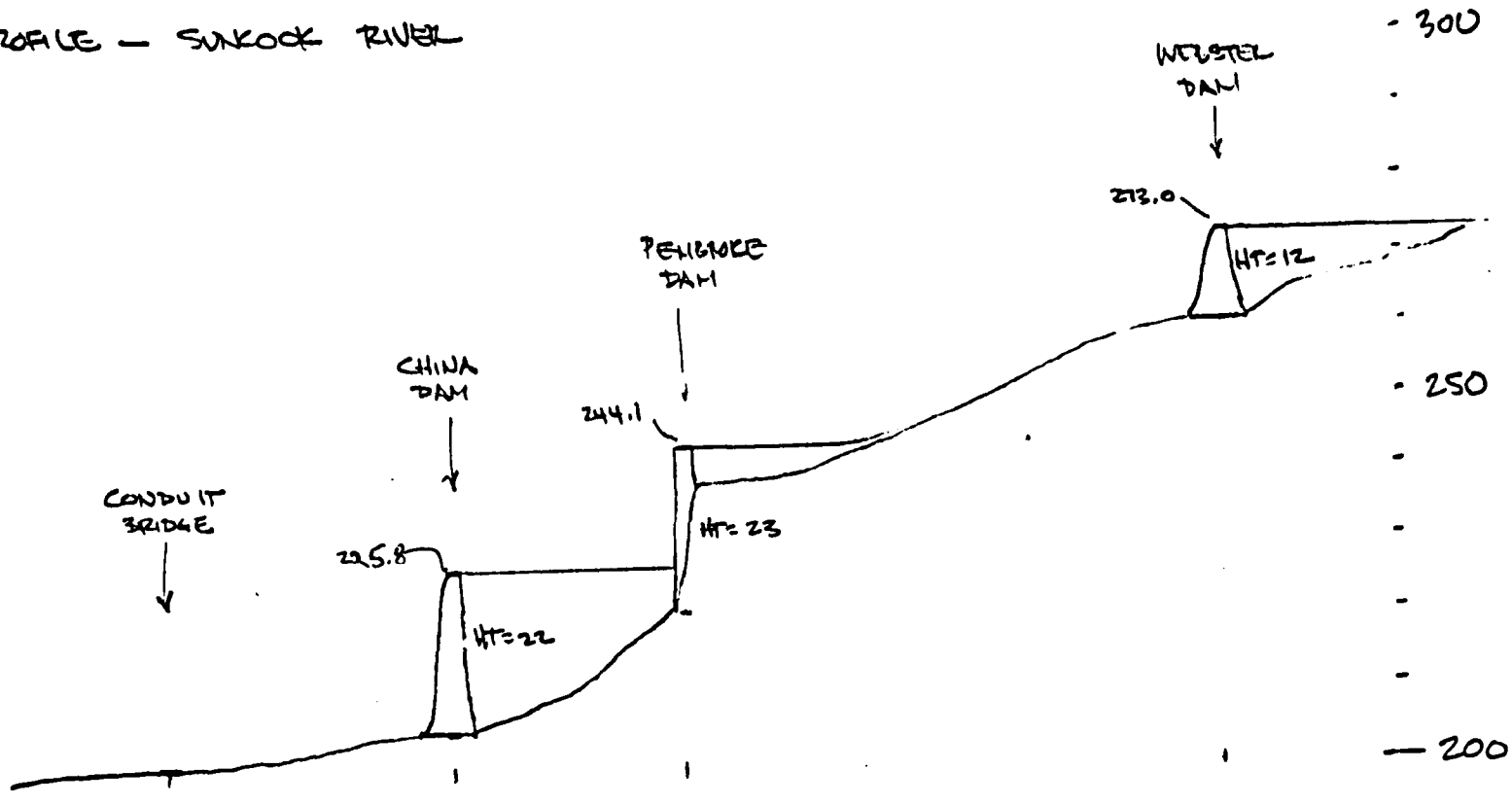
Discharge - Elevation Curve 650' Downstream of Pembroke Dam




SUNCOOK RIVER DOWNSTREAM OF PEMBROKE DAM
SCALE: 1" = 400'
1000'
Main St. Bridge
Old Mill
WEBSTER DAM
PEMBROKE DAM
Houses about
650' d.s. of
Pembroke Dam
CHINA DAM
Houses d.s.
of China Dam
Conduit
China Mill
MERRIMACK R.
SUNCOOK R.


FLOOD PROFILES
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
LEGEND
500 YEAR FLOOD
100 YEAR FLOOD
50 YEAR FLOOD
10 YEAR FLOOD
STREAMBED
CROSS SECTION LOCATION
PEMBROKE STREET-ROUTE 3 BRIDGE
WEBSTER DAM
MAIN STREET BRIDGE
DAM
CHINA MILL DAM
SEWER TRESTLE
BACKWATER FROM MERRIMACK RIVER
CONFLUENCE WITH MERRIMACK RIVER

PROFILE — SUNCOOK RIVER



P-14

China Dam is the next structure likely to be affected by the failure of Pembroke Dam. A BASIC program to calculate the Stage-Discharge curve at China Dam is given on pp. 16-17. This program is documented in the China Dam report.

Before Failure: 1850 cfs → h=2.3' (4.7' below dam crest)

After Failure: 4690 cfs → h=4.3' (2.7' below dam crest)

Below China Dam there are: a sewer trestle crossing the Suncook, several houses on the north bank (at elevation 216.0' MSL), and China Mill on the south bank (at about elevation 205' MSL). These structures are at a high enough elevation to escape damage from the Pembroke Dam failure outflow. About 2250' below China Dam the Suncook enters the Merrimack River.

```
LIST
100 REM: STAGE DISCHARGE PROGRAM FOR PEMBROKE CHINA DAM, JOB 165
110 REM: ON TAPE 10, FILE 60
120 PAGE
130 PRINT "DISCHARGE FROM CHINA DAM AS A FUNCTION OF HEAD"
140 PRINT USING 150:
150 IMAGE // 2T"HEAD"30T"DISCHARGE"
160 PRINT USING 170:
170 IMAGE 1T"(FEET)"32T"(CFS)"
180 PRINT USING 190:
190 IMAGE 15T"TOTAL"8X"LEFT BANK"8X"RIGHT BANK"8X "SPILLWAY"
200 FOR H=0 TO 13 STEP 0.5
210 Q1=0
220 Q2=0
230 Q4=0
240 Q5=0
250 Q3=3.7*143*H↑1.5
260 IF H<=7 THEN 320
270 Q2=2.5*37*(H-7)↑1.5
280 Q4=3.3*30*(H-7)↑1.5
290 Q5=2.8*20*(H-7)*(0.5*(H-7))↑1.5
300 IF H<=9 THEN 320
310 Q1=2.8*10*(H-9)*(0.5*(H-9))↑1.5
320 T1=Q1+Q2
330 T2=Q5+Q4
340 T3=T1+T2+Q3
350 PRINT USING 360:H,T3,T1,T2,Q3
360 IMAGE 2T,2D.1D,14D,15D,18D,17D
370 NEXT H
380 END
```


P.16

DISCHARGE FROM CHINA DAM AS A FUNCTION OF HEAD

HEAD (FEET)	DISCHARGE (CFS) TOTAL	LEFT BANK	RIGHT BANK	SPILLWAY
0.0	0	0	0	0
0.5	187	0	0	187
1.0	529	0	0	529
1.5	972	0	0	972
2.0	1497	0	0	1497
2.5	2091	0	0	2091
3.0	2749	0	0	2749
3.5	3464	0	0	3464
4.0	4233	0	0	4233
4.5	5051	0	0	5051
5.0	5916	0	0	5916
5.5	6825	0	0	6825
6.0	7776	0	0	7776
6.5	8768	0	0	8768
7.0	9799	0	0	9799
7.5	10939	33	39	10868
8.0	12183	93	119	11972
8.5	13518	170	236	13112
9.0	14939	262	392	14286
9.5	16447	367	587	15493
10.0	18045	491	823	16732
10.5	19737	633	1102	18002
11.0	21525	796	1426	19303
11.5	23410	981	1796	20634
12.0	25396	1188	2214	21994
12.5	27485	1420	2682	23383
13.0	29677	1676	3201	24800

TEST FLOOD ANALYSIS

SIZE CLASSIFICATION: SMALL

HAZARD CLASSIFICATION: LOW

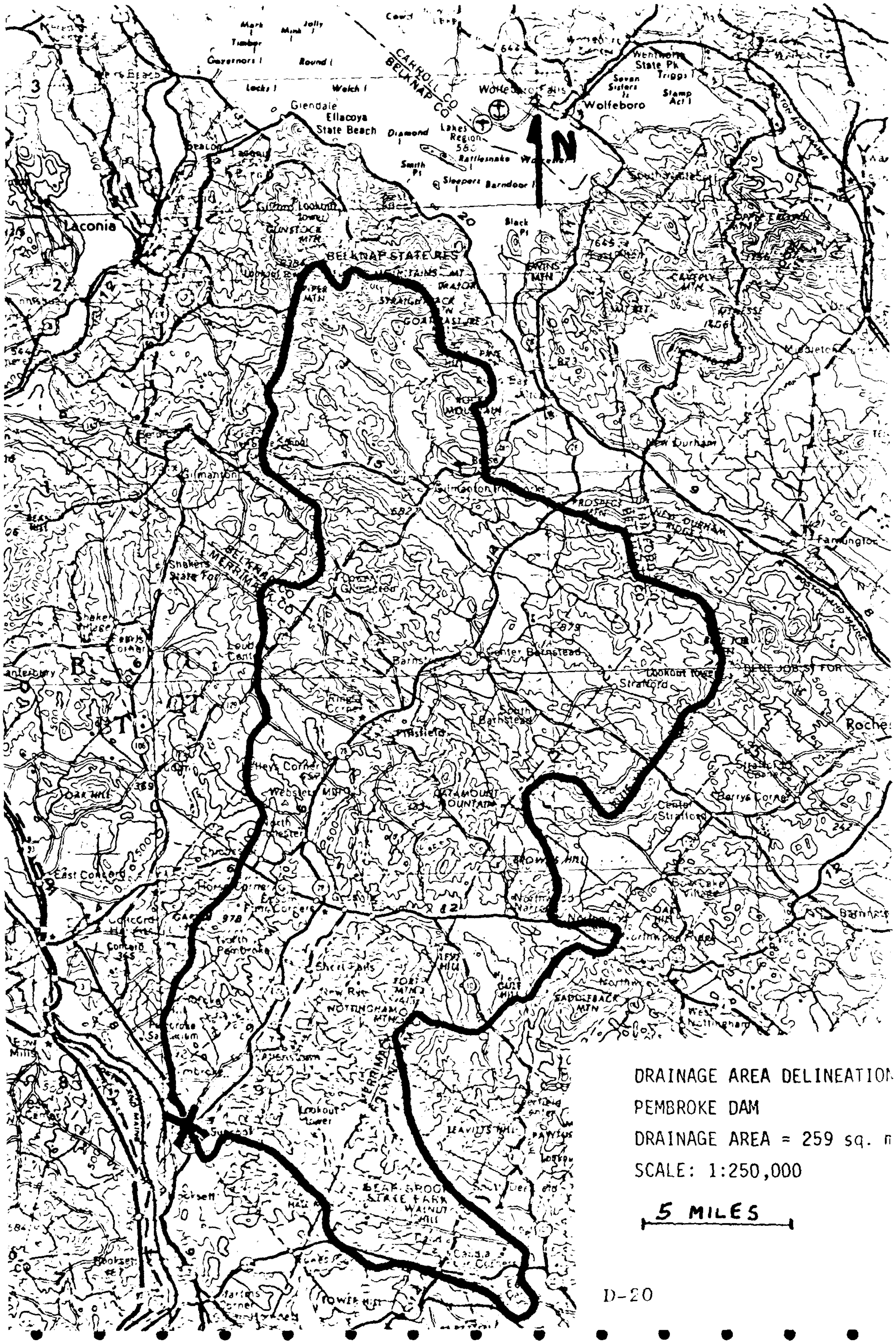
The hazard classification is low because the failure of Pembroke Dam would create little or no significant downstream flooding. The failure would cause a 1-2' rise in the downstream water surface, but the surface would still be well below a hazardous level.

Test Flood: 50 to 100 year

Anco gives a 50 year discharge of 12,190 cfs and a 100 year discharge of 15,115 cfs. Because the hazard is on the low side of low, we will use 12,190 cfs. ($\frac{12190 \text{ cfs}}{259 \text{ sq mi.}} \rightarrow 47.07$ csm.)

Due to the large drainage area (see p. 19) and small available storage (Storage-Elevation Curve p. 21), this flow would not be significantly attenuated by the pond behind Pembroke Dam.

The flow of 12,190 cfs would produce a stage of about 12.4 feet above the spillway (8.4' above the dam crest, elevation 256.5). It is worth noting that Anco's 10 year flow of 6990 cfs would produce a stage 8.9' above the spillway, overtopping the abutments by 4.9 feet.



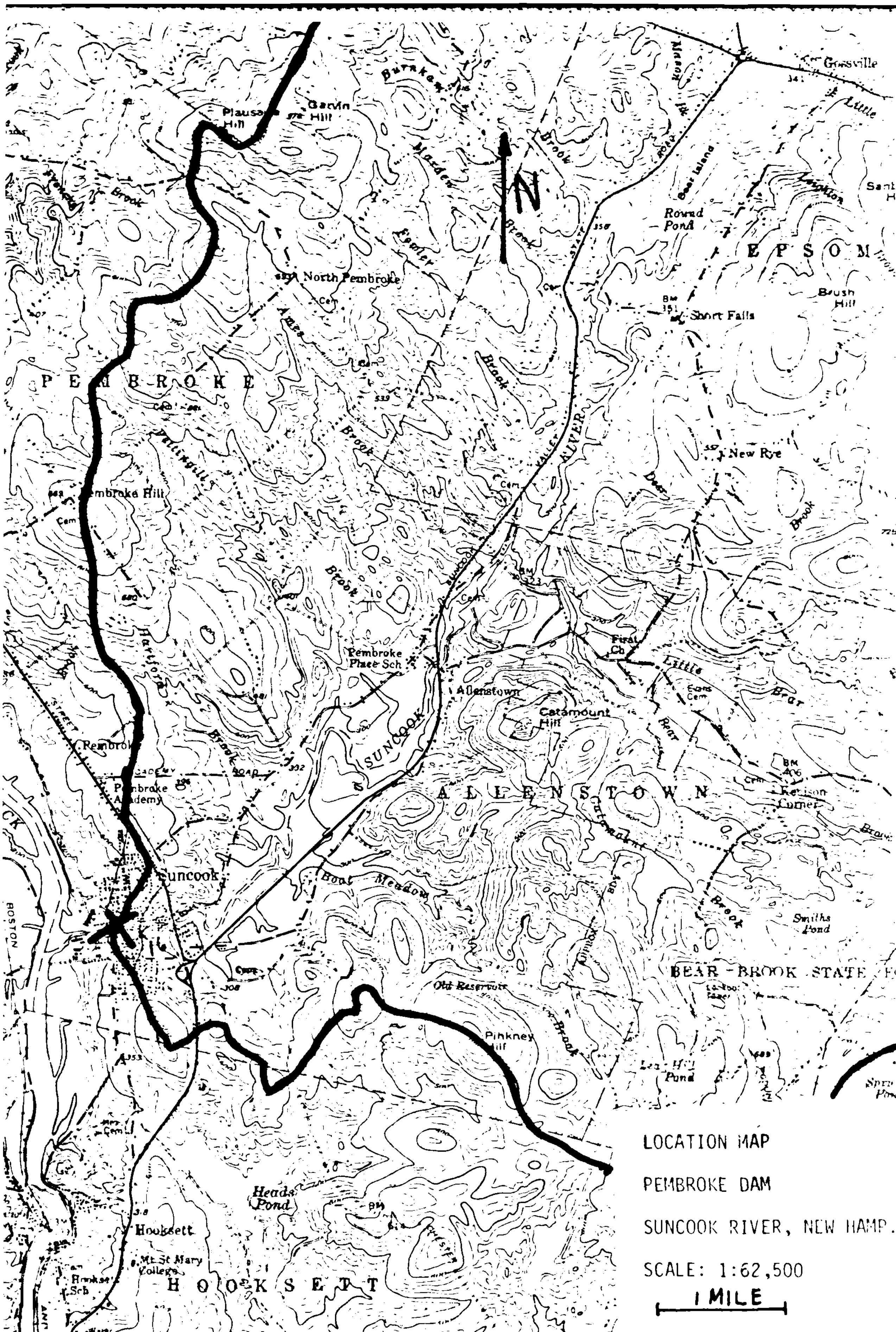
DRAINAGE AREA DELINEATION

PEMBROKE DAM

DRAINAGE AREA = 259 sq. mi

SCALE: 1:250,000

5 MILES



LOCATION MAP

PEMBROKE DAM

SUNCOOK RIVER, NEW HAMP.

SCALE: 1:62,500

1 MILE

165 Dam Safety Pembroke Dam, #15 TCG, 2/12/79, I

Storage-Elevation Curve

The storage-elevation curve for Pembroke Dam is given on p. 21. This curve is based on a surface area of one acre and the assumption that the pond does not spread as it rises

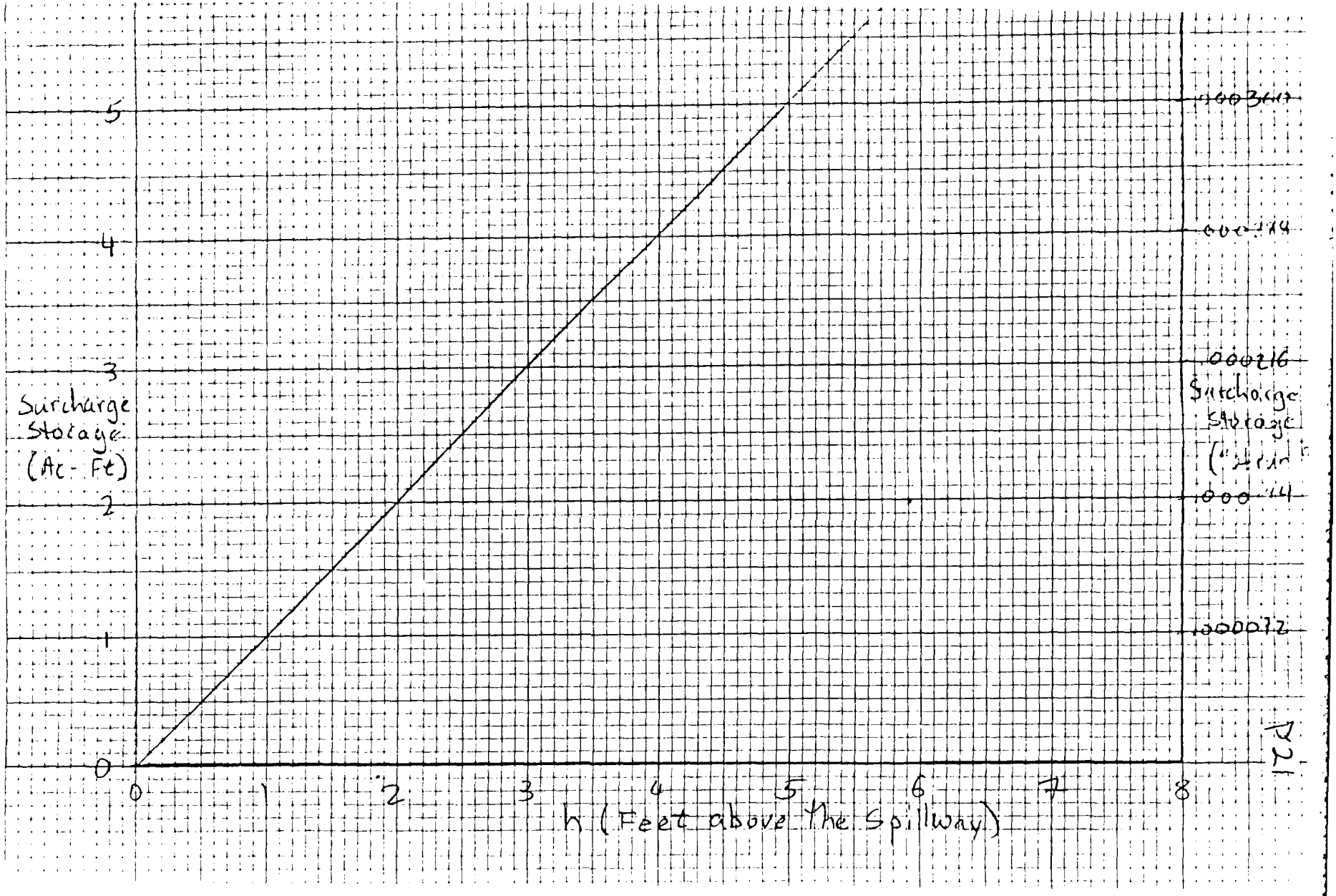
1" of runoff over 259 sq. mi.

$\rightarrow 1'' \ (259 \text{ sq. mi.}) \left(640 \frac{\text{acres}}{\text{sq. mi.}}\right) \left(\frac{1 \text{ ft.}}{12''}\right)$

$= 13{,}813$ AC-FT.

So 1 AC-Ft of storage $= \frac{1}{13{,}813} = .000072''$ of runoff

1' of rise will store .000072" of runoff.


Surcharge Storage (Ac-Ft)
0
1
2
3
4
5
0
1
2
3
4
5
6
7
8
h (Feet above the Spillway)
Surcharge Storage

APPENDIX E

INFORMATION AS CONTAINED IN THE NATIONAL INVENTORY OF DAMS

END

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7-85

DTIC